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CARRY FALLS RESERVOIR INVESTIGATION[1]

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ABSTRACT

Studies were conducted during July and August in 1951 and 1955 to determine conditions in a 9-mile section of the Raquette River in St. Lawrence County before and after impoundment. The 3,200-acre impoundment, completed in 1953 under a Federal license and known as Carry Falls Reservoir, was for the purpose of storing and regulating the flow of water for the development of hydroelectric power downstream.

Fishermen from a wide area utilized the fish resource. Fishing pressure was light to moderate, although the total effort more than doubled following impoundment. Public use of the reservoir was encouraged by the power company, which provided access sites.

The quality of the fishing was mediocre before and after impoundment, except that bullhead fishing became quite good following a great increase in the bullhead population after impoundment. Smallmouth bass and northern pike were the principal game species present; the growth rate and rate of catch for these species showed little change. On the average, it required over 3 hours to catch a fish (all species combined) in 1951, and ¾ hour in 1955. The total summer catch in 1955 was estimated to have increased over 20 times in number and 10 times in weight, the increase consisting mainly of bullheads.

It was found that natural spawning was adequate to maintain the population of fish of angling importance without additional stocking of hatchery fish.

The impoundment of the river resulted in gains in the over-all production and utilization of the fish resource, although some limitations probably resulted from the great fluctuation of water level which was necessary in operation of the reservoir. No harm to tributary trout waters was noted.

No changes in fishing regulations or other management methods were recommended.

A large number of artificial reservoirs have been constructed in the United States, and many more are being proposed for the future. In many cases these impoundments have been of vital concern to the state and Federal conservation agencies. It has become imperative, therefore, to attempt to evaluate the effects of these impoundments early in the planning stages in order to assure adequate consideration of the fish and wildlife resources involved.

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[1] The general plan for the entire study was originally organized (and supervised in the preimpoundment phase) by Dr. W. M. Lawrence, then Senior Aquatic Biologist, New York State Conservation Department, and Albert H. Swartz, then Biologist, River Basin Studies, U. S. Fish and Wildlife Service. The post-impoundment phase was organized and supervised by the writer as Federal Aid in Fish and Wildlife Restoration Project F-12-R-1.

Such evaluations have been made under the amended "Coordination Act" (Public Law 732, 79th Congress), which provided the authority for consideration of biological resources in Federal construction programs or projects licensed by Federal agencies.

It became increasingly apparent that more accurate determinations of the effects of these water developments on fish and wildlife resources were needed to perform intelligently the function assigned under this authority. To meet certain phases of this problem in cooperation with the states involved, the U. S. Fish and Wildlife Service undertook a long-range program of study. This program was designed to provide basic information for the following responsibilities:

1. To predict accurately the effects of proposed impoundments on fish and wildlife resources.
2. To devise ways and means for minimizing damage to existing fish and wildlife resources.
3. To manage the resources of these impoundments for maximum production and utilization.

An opportunity to carry forward that aspect of the over-all program concerned with fisheries was presented in 1951 when the Federal Power Commission issued a license authorizing impoundment of the Raquette River at Carry Falls. A suitable site was now available where there would be a minimum delay between preproject and postproject comparative observations. Pending plans for intensive development of the Raquette River for hydroelectric power lent added importance to a study at Carry Falls. Information gained on the results of impoundment at this point might well be useful in the management of the fisheries in the power pools to be created downstream so that maximum benefits compatible with other uses and values would be assured.

A cooperative fisheries investigation was organized by the New York State Conservation Department and the United States Fish and Wildlife Service to determine:

1. Abundance, composition, and characteristics of the existing fish population and changes therein following impoundment.
2. Levels of utilization (angling harvest) before and after impoundment.
3. Pertinent physical, chemical, and biological aspects of the environment before and after impoundment.

The investigation was carried out as planned. In the present account, the preimpoundment and postimpoundment phases have been treated separately, followed by a discussion of findings and the conclusions drawn.

PREIMPOUNDMENT STUDY

During the summer of 1951, while the dam at Carry Falls was under construction, a study was made in the area to be impounded.

PROCEDURE

A biologist was stationed in the area from late June to early September to conduct a creel census, make observations and collect other data pertinent to the objectives of the study. Personnel from the State's district fisheries office at Saranac Lake also visited the project at intervals to make fish collections by means of seines and gill nets at scattered points along the river and to make chemical analyses of the water.

The creel census was conducted three days a week—Saturday, Sunday and one week day selected at random, with the restriction that each of the different week days be included at least once. A dirt road, known as the Hollywood road, paralleling the river on the west side made it possible to drive readily by car to the many check points. The 9-mile section of river to be impounded by the dam being built at Carry Falls was patrolled in this way on census days from 9 a.m. until fishing activity ceased in the evening. Fishermen were checked from shore, with a special effort being made to conduct personal interviews with as many of them as possible at the conclusion of their fishing. Counts were also made of anglers observed but not contacted. In estimating total effort and catch, adjustments were made to allow for these anglers and for days on which the census did not operate. These adjustments were based on the assumption that the fishing effort (number of anglers and hours fished) and the rate of catch (hours per fish) for days not checked during a month were the same as the average values for days which were checked during the same month.

FINDINGS

Findings have been divided into three main categories, the first relating to the environment, the second to the fish therein, and the third to the utilization of the fish resource.

General Description of the Area

The various features of the environment were given individual study.

Physical Features Carry Falls was located on the Raquette River in the town of Colton in eastern St. Lawrence County at a point approximately 67 miles upstream from its confluence with the St. Lawrence River. The dam to be built there would impound the river upstream to Jamestown Falls, a distance of approximately 9 miles. This section of the river flowed in a south to north direction through rather wild, wooded land, typical of the 875 square miles of Adirondack Mountain country draining into it. The general region was sparsely populated. Several small villages were within 20 miles driving distance, but their total resident population did not exceed about 20,000. However, there was normally a considerable influx of tourists during the summer vacation period.

Of the almost 9 miles of river in the section to be impounded, nearly 7½ miles consisted of stillwater, divided into three separate sections by two stretches of rapids. The stillwaters varied from about 200 feet to one-quarter mile in width, with a depth of 5 to 7 feet in the main channel. The rapids varied from about 100 feet to 300 feet in width, with a depth generally less than 3 feet. The bottom was composed primarily of bed-rock, boulders, gravel and sand, particularly in the rapids; however, in the quiet sections of the stillwaters there were extensive accumulations of muck and mud.

The river dropped about 70 feet in elevation, almost entirely in the 2 miles of rapids, between Jamestown Falls and Carry Falls. Although little current was perceptible in the stillwaters, the flow was swift and turbulent in the intervening rapids. Numerous pools of varying size were scattered through these rocky rapids, providing excellent habitat for smallmouth bass.

Carry Falls and Jamestown Falls constituted barriers to upstream movement of warm-water species of fish. Thus, fish from downriver were prevented from entering the study section, while fish within the section could not move out of it in an upstream direction.

The volume of flow over a 30-year period averaged from 1,500 to 1,800 cubic feet per second. The lowest volumes occurred in late summer—660 in August and 630 in September. A high of 10,000 cubic feet per second occurred in May 1943. All through July and most ot August in 1951 the river was very high, almost to spring level.

During the summer of 1951, the impoundment area was cleared

of forest cover, which was made up mainly of yellow birch, red maple, poplar, red spruce, and tag alder. The trees and brush were cut close to the ground, and unusable cuttings were piled and burned.

A total of 30 tributaries emptied into the Raquette River in the section to be impounded. Of these, 13 were brook trout streams, most of which were quite small and had self-maintaining populations of small-sized trout. The others were very small or even dry most of the time.

Only two of the streams had much value for trout angling. One was Cold Brook, which averaged about 15 feet wide in its lower course and had a flow of about 10 cubic feet per second in midsummer. The other was a large stream, the Jordan River, which averaged about 40 feet wide in its lower course and had a flow of about 20 cubic feet in midsummer. The lower end of the Jordan River became quite warm during the summer months; but some brook trout were reported to be caught in that section each year, mainly during the spring season.

There was a sliding rock falls on the Jordan River about a mile above its confluence with the Raquette River. This falls was about 5 feet high and probably was no barrier to upstream movement of trout, at least during high water. However, warm-water species such as bass and pike were not reported present above it, although they were sometimes caught up to this point. Therefore, it seems likely that the falls constituted a barrier to upstream movements of warm-water species from the Raquette River.

On Cold Brook, about 2 miles from its mouth, there was also a small falls about 2 or 3 feet high. This may also have served as a barrier to upstream movement of warm-water fish. However, the coldness of the water in this stream would serve as a natural deterrent to the entry of such species from the river.

TEMPERATURES During July and August water temperatures taken in late afternoon varied from 65° to 75° F., averaging about 70°; while air temperatures taken at the same time varied from 50° to 82° F., also averaging about 70°. No significant temperature stratification was noted at any time in the waters of the river.

CHEMICAL FEATURES The chemical condition of the water was good, as might be expected in a shallow, unpolluted river.

Chemical analyses were made on July 5, July 25 and August 24 at the upper and lower limits of the study area and also in between with samples being taken from both rapids and stillwaters, at the surface and bottom (down to 12 feet maximum depth). With tempera-

tures ranging from 61.5° to 75° F., dissolved oxygen values varied between 6.4 and 8.4 p.p.m.—an abundant amount for all types of fish life. Carbon dioxide concentrations were low—2 p.p.m. or less. Methyl-orange alkalinity readings averaged 12.3 p.p.m. $CaCO_3$, indicating rather soft water. The pH varied from 6.1 to 6.8, slightly on the acid side. No tests were run for color or turbidity, but superficially the water appeared to be moderately turbid and showed the typical Adirondack brown color. Transparency was low.

Aquatic Vegetation Pond weeds were quite common. Seven species were recognized, but only *natans, crispus, gramineus* and *richardsonii* of the genus *Potamogeton* were identified. Water lilies (both *Nuphar* and *Nymphaea*) were common in back bays and around islands in the stillwaters. Quillwort (*Isoetes*) was common throughout most of the section.

Among the emergent aquatics, bur reed (*Sparganium*) was common along shore in all of the stillwaters. Arrowhead (*Sagittaria latifolia*) and pickerelweed (*Pontederia cordata*) were rare, occurring only in a few locations.

Bulrush (*Scirpus*) was common on the islands and along shore in the back bays. Spike rush (*Eleocharis*) also was found commonly along shore throughout the area.

Fish Population

Information relative to the various species of fish occurring in the river was obtained from angling, seining, gill netting and general observation.

Composition, Abundance and Distribution Following is a list of the species found present, with a rough estimate of their relative abundance:

Smallmouth black bass *(Micropterus dolomieu)*	Abundant
Northern pike *(Esox lucius)*	Common
Yellow pikeperch *(Stizostedion vitreum)*	Uncommon
Brook trout *(Salvelinus fontinalis)*	Rare
Yellow perch *(Perca flavescens)*	Common
Rock bass *(Ambloplites rupestris)*	Fairly common
Common sunfish *(Lepomis gibbosus)*	Rare
Common sucker *(Catostomus commersonnii)*	Fairly common
Fallfish *(Semotilus corporalis)*	Abundant
Blacknose shiner *(Notropis heterolepis)*	Fairly common
Golden shiner *(Notemigonus crysoleucas)*	Uncommon
Common bullhead *(Ameriurus nebulosus)*	Fairly common

The smallmouth bass was the principal gamefish in this section of the river. There was a very large population of 6- to 9-inch bass, particularly in the fast-water sections. In the stillwaters, bass were less common but ran larger in size. A few bass reached a weight of over 3 pounds, two of this size being reported caught by angling.

Northern pike ranging up to 6 pounds or more in weight occurred, principally in the stillwaters. This species ranked second to the bass in importance to anglers.

Smallmouth bass and northern pike were caught in the area as long ago as local residents could remember.

Yellow pikeperch (walleyes) may have been more abundant than the study during the summer months indicated, for local residents reported fairly good fishing for this species in the spring. Two weighing over 3 pounds were netted and two over 5 pounds were reported caught by angling. This species was reportedly introduced about 1916.

Although brook trout were common in several cold streams tributary to this section of the Raquette River, only one specimen was reported caught in the river itself.

Yellow perch were found in all the stillwaters. The young in the 2- to 3-inch class were used quite often as bait.

Fallfish were abundant throughout the area. The younger fallfish from 2 to 6 inches long were found in the weedy backbays, while the larger adults were caught in the fast water. This species was greatly used for bait and also appeared to be the most important forage fish in the area.

Rock bass, sunfish, bullheads, suckers and shiners were generally found in the stillwater areas of the river. Local residents claimed that bullheads were very abundant at one time in the past, but that their numbers had been steadily decreasing. Only one sunfish was reported caught by anglers.

GROWTH RATE Scale samples were removed from fish taken both by angling and by netting. These scale samples were later examined carefully by means of a binocular microscope, the scales being immersed in water held in a watch glass. It was found that the scales from the northern pike and yellow perch exhibited numerous checks or false annuli which made it impossible to determine ages with any great degree of confidence. The same condition was found to exist when scale samples were taken in the postimpoundment study. Also, only relatively small numbers of scale samples were available for comparison from non-gamefish species; and, since these same species were

of minor importance in the fishery, no critical treatment of their rates of growth has been attempted.

The smallmouth bass produced scales with clearly-formed annuli; and, since they were the most important gamefish present, data on their growth are presented (see Table 6). The data in this table have been limited to include bass taken from mid-July to mid-August only. By using scale samples taken during this short period for comparison with samples taken during a similar period in the postimpoundment study, it was believed that readings would be more accurate and comparable than if the samples had been taken over a longer portion of the summer growing season. For one thing, the possibility of incorrectly identifying marginal annuli would be eliminated, since all of the bass had completed formation of the last annulus before the middle of July. On the average, it required 4 to 5 years for a bass to grow to the legal length of 10 inches. This represents a fairly good, or at least average, rate of growth for bass in this part of New York State. It should be pointed out that the small size of the many bass occurring in the rapids section of the river was associated with their youthful age and not with a slow rate of growth.

Older age groups were poorly represented in the bass population, although a couple of 3-pound bass which were probably old fish were reportedly caught. A theory was advanced that the seemingly poor longevity of the bass might be due to the hazards and hardships of the river-type environment.

Scale samples were available from only a few pikeperch. Scale readings indicated that the legal length of 12 inches was reached in 3 years or less. Six of the eight fish in the sample measured from 20 to 24 inches in length. Scales from these large fish were also difficult to read with certainty, but some appeared to be at least 10 years old. In view of the fairly large size reached by pikeperch in the river, it appears probable that the rate of growth for this species was generally good throughout life.

Reproduction Conditions were poor for observation and seining, with the result that it was difficult to make a fair estimate of the success of natural reproduction in the area. For example, no bass spawning beds were observed, and only one bass fry was seen. Yet, in view of the large existing population of bass and the presence of large areas of bottom suitable for spawning, there can be little doubt that there was ample natural reproduction by this species.

Probably conditions were favorable for natural reproduction by all

of the species present. Fallfish and yellow perch fry were common and observed in all sections. Immature and fry northern pike were seen and taken in fair numbers. Sucker fry seemed to be rare, but this scarcity may have been more apparent than real. Young rock bass were often taken during seining operations.

A limited amount of hatchery stocking with smallmouth bass and pikeperch fry had been done in the past in this section, but it seems unlikely that such artificial methods contributed much to the maintenance of these species.

UTILIZATION Based on knowledge of past angling activity in the study area, fishing pressure there could generally be termed as moderate under normal conditions. However, for various reasons, fishing pressure during 1951 was much lower than in normal years. The camp owners were all busy tearing down their camps, and the dam construction and clearing operations discouraged many fishermen from coming into the area. Also, the Hollywood Hotel, which in past years catered to hunters and fishermen, was only operating as a boarding house for the workers on the dam project. In addition, high water levels during July and August made the rapids almost impossible to fish and discouraged many fishermen from fishing the stillwaters. Local residents and campers estimated that fishing pressure in all areas except the Jamestown stillwater was no more than half the normal pressure. The Jamestown stillwater, which was the furthest removed from the dam site and which was untouched by clearing crews throughout the summer, appeared to have what could be considered normal fishing pressure.

The two areas that received the most fishing pressure were the Hollywood stillwater and the Jamestown stillwater. The Hollywood stillwater extended from Carry Falls upstream to Halls Rapids, a distance of 4½ miles. The Hollywood Hotel, which rented boats, and numerous camps and access areas were on that stillwater. The Jamestown stillwater, on the upper end of the study area, ran from Jamestown Falls down to Long Rapids for about 1⅜ miles. There was one boat livery there, one large camp, and one excellent public access road from which fishermen often put in boats. The remaining sections of the area, which were all fast water with the exception of one fairly inaccessible stillwater ¾ mile long between Halls Rapids and Long Rapids, were very lightly fished.

Fishing pressure varied during the course of each week. It was low on week days, moderate on Saturdays, and heaviest on Sundays.

Very little fishing was done in the late evening or at night, probably because of the swarms of small, biting flies known as "punkies" which appeared as soon as the sun went down.

Since the creel census was in operation only during a limited portion of the year, and since the proportion of the year's total catch as represented by the data was unknown, no estimate could be made as to the yield of fish for the year as a whole. Certain species, such as northern pike and pikeperch, were reportedly taken more readily in May and June. However, the bulk of the year's fishing pressure undoubtedly occurred during the midsummer vacation period, including the months of July and August. Also, there was no closed season on any species in July and August. Therefore, creel census data for these two months only were chosen for comparison with data taken during the same period in the postimpoundment study. Although these data give an indication of total yields from the area before and after impoundment, they are mainly useful as a measure of the relative quality of fishing and of shifts in kinds and sizes of fish caught.

Fishermen came from a wide area to fish in this section of the river (see Table 7). About 70 per cent of them fished from boats and 30 per cent from shore. Anglers fished 3.2 hours and each caught one fish, on the average.

In Table 1 are summarized the sampling data on the anglers' effort and catch as actually recorded from personal interviews during

Table 1. Recorded Angling Effort and Catch from Completed Fishing Trips in the Carry Falls Section of the Raquette River in 1951 and 1955

Item			Species							
Period	Anglers	Hours	Smallmouth bass	Northern pike	Pikeperch	Bullhead	Yellow perch	Rock bass	Fallfish	Total
1951										
July	124	432	37	14	0	5	19	16	31	122
August	85	238	26	5	1	2	14	30	3	81
Total	209	670	63	19	1	7	33	46	34	203
1955										
July	218	806	64	27	0	962	5	7	4	1,069
August	214	621	40	11	5	942	7	6	4	1,015
Total	432	1,427	104	38	5	1,904	12	13	8	2,084

TABLE 2. ESTIMATED TOTAL ANGLING EFFORT, AND COMPOSITION AND RATE OF CATCH, IN THE CARRY FALLS SECTION OF THE RAQUETTE RIVER IN 1951 AND 1955

Item			Species							
Period	Anglers	Hours	Smallmouth bass	Northern pike	Pike-perch	Bullhead	Yellow perch	Rock bass	Fallfish	Total
1951—All anglers										
July	249	870	74	28	0	10	38	32	62	244
August	199	556	61	12	2	5	33	70	7	190
Total	448	1,426	135	40	2	15	71	102	69	434
Per cent of catch			31.0	9.4	0.5	3.4	16.3	22.7	16.7	100.0
Hours per fish			11	35	670	96	20	15	20	3.3
1955—Car anglers										
July	884	3,271	260	109	0	3,906	20	28	16	4,339
August	671	1,946	125	34	16	2,948	22	19	13	3,177
Sub-total	1,555	5,217	385	143	16	6,854	42	47	29	7,516
1955—Other anglers										
Sub-total	206	788	142	47	2	318	99	36	0	644
1955—All anglers										
Total	1,761	6,005	527	190	18	7,172	141	83	29	8,160
Per cent of catch			6.5	2.3	0.2	87.9	1.7	1.0	0.4	100.0
Hours per fish			11	32	334	0.8	43	72	207	0.7

July and August, while the estimated total angling effort and catch are given in Table 2. The size of the sample on which the estimate was based amounted to approximately half the estimated total.

Undoubtedly there was considerable selection by anglers as to size and species of fish saved, so the composition of the catch did not necessarily represent the true relative abundance and availability of the various species. Only data on fish caught and kept have been included in the tables. However, small perch and fallfish which were saved as bait were not counted in the catch. Fallfish were not generally regarded as choice panfish, but some anglers apparently considered the larger individuals to be worth keeping. Bass of sub-legal size were caught in large numbers, particularly in the fast water. Fishermen's reports of fish thrown back revealed that about 75 per cent of the bass and 20 per cent of the pike caught were undersized and had to be

released. The average sizes of the fish caught and saved are given in Table 3 and the estimated total weights in Table 4. Daily legal catch and minimum size limits (total lengths) were as follows: smallmouth

Table 3. Average Length and Weight of Fish Caught in the Carry Falls Section of the Raquette River in 1951 and 1955

Species	1951				1955			
	Number	Minimum	Maximum	Average	Number	Minimum	Maximum	Average
				Total length in inches				
Smallmouth bass	48	10.0	14.3	11.6	56	10.0	14.8	12.4
Northern pike	18	18.0	31.3	22.1	48	18.3	28.3	22.0
Pikeperch	1	..	..	20.4	2	12.2	12.9	12.6
Bullhead	8	8.0	13.8	10.2	114	4.7	11.6	7.6
Yellow perch	15	7.1	12.0	8.8	13	5.9	11.1	8.9
Rock bass	9	5.5	8.5	6.5	9	5.7	10.2	7.7
Fallfish	8	7.5	14.3	10.4	4	6.9	8.4	7.5
				Weight in ounces*				
Smallmouth bass	..	..	..	12	56	8	28	16
Northern pike	..	..	..	37	41	15	79	37
Pikeperch	..	..	..	40	2	10	12	11
Bullhead	..	..	..	10	114	1	13	4
Yellow perch	..	..	..	5	13	2	9	5
Rock bass	..	..	..	4	9	2	9	5
Fallfish	..	..	..	6	4	2	4	3

* Adequate weight data not recorded in 1951; average values estimated from weights of fish of corresponding size taken in 1955.

Table 4. Estimated Total Weights of Fish Caught in the Carry Falls Section of the Raquette River in 1951 and 1955 *

Species	1951		1955	
	Pounds	Per cent	Pounds	Per cent
Smallmouth bass	101	36.0	527	18.5
Northern pike	93	33.1	439	15.4
Pikeperch	8	2.8	12	0.4
Bullhead	9	3.2	1,793	63.0
Yellow perch	22	7.8	44	1.6
Rock bass	26	9.3	26	0.9
Fallfish	22	7.8	5	0.2
Total	281	100.0	2,846	100.0

* Based on data in Tables 2 and 3.

bass—6 fish, 10 inches; northern pike—10 fish, 18 inches; pikeperch—10 fish, 12 inches; others (except trout)—no limits.

POSTIMPOUNDMENT STUDY

Construction of the Carry Falls Dam was completed in 1952, and the reservoir was first filled in the spring of 1953. The postimpoundment study was scheduled for the summer of 1955. Thus over two full years had elapsed during which the effects of impoundment could become apparent.

Procedure

In general, procedures were similar to those employed in 1951. One man was assigned to the reservoir area from late June to early September to conduct a creel census and collect other pertinent data; while State biologists, this time from the district fisheries office at Watertown, visited the reservoir to make periodic chemical analyses of the water and to collect samples of the fish population.

Chemical Analyses

At the end of each month chemical analyses were made of water samples taken from various depths at two stations. The upper station was located below the original Long Rapids section and opposite the access point on the old Hollywood road, while the lower one was at the broadest and deepest part of the reservoir about 2 miles above the dam. The straight Winkler method was used for oxygen determinations.

Temperature Studies

Air and water temperatures were taken from the upper part of the reservoir in the vicinity of the old Hollywood road at about 2:30 p.m. (E.S.T.) on days when the creel census operated. A mercury pocket thermometer was used and was held a few inches below the surface when taking water temperatures. A series of water temperatures at various depths was taken in conjunction with the chemical samples. A thermister-type electric thermometer was used for this purpose.

Fish Population Studies

Information regarding the fish population was obtained from the creel census, from general observations, and from netting. Observations and shore seining were conducted on June 29 in search of young fish.

Extensive fish collections from various parts of the main body of the reservoir were made during the period of July 25-27. Minnow seines and trap nets were used at this time along shore, while gill nets of from 1½- to 3½-inch stretched mesh were fished in both shallow and deep water. Total lengths of fish (from tip of snout to tip of tail compressed) were measured on boards calibrated in tenths of an inch. Weights were taken to the nearest ounce on Chatillon straight spring package scales having a capacity of 64 ounces with 1-ounce graduations.

Creel Census

The creel census presented a more difficult sampling problem than that encountered in the preimpoundment study. Fishing pressure had increased considerably; and the old Hollywood road, which had paralleled the river, was largely inundated. State highway Route 56, which also runs parallel to the same side of the reservoir, but further away, was used for patrolling. This necessitated driving long distances to check all the access points. However, a special effort was made during the first four weeks of the creel census to cover all the possible points of approach to the reservoir throughout the day in order to determine the sources and distribution of fishing pressure.

It quickly became apparent that the most effective way to get a measure of the total fishing pressure was to count and check car anglers, since nearly all fishermen reached the reservoir in cars. In addition, a few private summer camps were located around the reservoir, and their occupants were requested to record their fishing effort on blanks provided them for that purpose. The campers were cooperative in keeping records, which were collected later by the census taker.

The creel census was conducted on Saturdays, Sundays, and one holiday (July 4), as well as usually on three week days during each week. Week days were scheduled so that days missed one week were included the following week in order to get as complete and even coverage as possible. On weekends the census operated from 9 a.m. until fishing activity ceased (usually about dark or shortly after); while on most week days the census was conducted from 2 p.m. on. The census taker shuttled back and forth by car between access points every hour or two, the length of stay at a particular access point depending to some extent on the number of cars present. Rarely did the period between checks at an access point exceed 3 hours. Car counts were

made at each visit, license numbers being checked in order to identify individual cars. It was also necessary to determine which cars belonged to sightseers and picknickers and which to fishing parties. Nearly all parties bringing boats came to fish. There were no boat liveries on the reservoir, so it was necessary for fishermen to bring their own boats or else fish from shore.

Emphasis was placed upon interviewing parties which had completed their fishing. Data were recorded as to the number of anglers in a party, their home town and state, type of fishing (boat or shore), time fished, type of lure, lengths and weights by species of fish caught and kept, and estimates of fish released. Scale samples were taken whenever possible.

There were three principal points of access to the reservoir by car. One was at the lower end of the dam, one at the upper end below Jamestown Falls and the other in between from the old Hollywood road. Cars could still drive over this road to the point where it disappeared under water. The location of this point depended upon the water level in the reservoir and varied from 2½ to 3 miles below Jamestown Falls. Fishermen starting from the Hollywood road could go by boat to all parts of the lower, main body of the reservior but were prevented from travelling up to the Jamestown stillwater area by the intervening Long Rapids, which reappeared in July when water levels began to fall.

The upper two access points were only a few minutes drive apart for the census taker; but a visit to the dam involved a comparatively long, round-about, time-consuming trip. It was, of course, desirable for the census taker to be on hand at access points as much time as possible in order to contact a maximum number of fishermen at the conclusion of their fishing. Therefore, during the latter half of July and most of August, the creel census was confined to the upper two access points in order to avoid considerable loss of time due to travel.

Car counts were made at all access points on 17 complete days between June 18 and July 11. The total numbers counted were 59 (28 per cent) at the dam, 76 (34 per cent) at the Hollywood road and 81 (38 per cent) at Jamestown Falls. Subsequently, on days when no counts were made at the dam, a correction factor of 1.4 (based on the foregoing counts) was applied to the sum of car counts made at the upper two access points. Additional car counts in mid-August at all three access points showed no shift in distribution of fishing pressure.

In order to get maximum coverage, the length of the creel census

on weekdays was shortened to cover the period of maximum fishing activity. Thus a greater number of days could be included for census within the limits set by the manpower available for the work. Of a total of 327 cars counted at the Hollywood and Jamestown access points on 37 complete census days scattered from late June to early September, 259 (79 per cent) were present and could have been counted by a census day beginning at 2 p.m. On this basis, the creel census on week days during the latter part of July and all of August was begun at 2 p.m., and a correction factor of 1.26 applied to counts made on these days to determine the total number of cars present at these two access points for the entire day.

Further adjustments were made to arrive at estimates of the total effort and catch for each month. Estimates of the number of cars present on weekdays when the creel census did not operate during a month were based on the average number of cars present on weekdays when the census did operate during the month. Estimates of the number of cars present, but not actually counted, during a month were added to the number of cars counted in order to get an estimate of the total number of cars for the month. This total was multiplied by the average number of anglers per checked car for the entire period of the census in order to obtain an estimate of the total number of anglers for the month. In turn, this total was multiplied by the average hours fished by checked anglers, giving an estimate of the total angling hours for the month. Then the total number of angling hours was divided by the monthly average of hours that anglers contacted at the end of their fishing took to catch a fish of each species; this provided an estimate of the total catch for the month by car anglers. Finally, the effort and catch reported by other anglers (mostly campers) were added to those of car anglers.

Findings

Findings have been grouped in the same sequence as in the preimpoundment section in order to facilitate comparisons.

General Description of the Area

In the postimpoundment study, the same features of the environment were given individual attention as in the preimpoundment study.

Physical Features Carry Falls dam was completed in 1952. It measured 830 feet long and 70 feet high. This concrete dam, together with five earth dikes, created a storage reservoir extending upstream about 8 miles to Jamestown Falls (Figure 1). This man-made

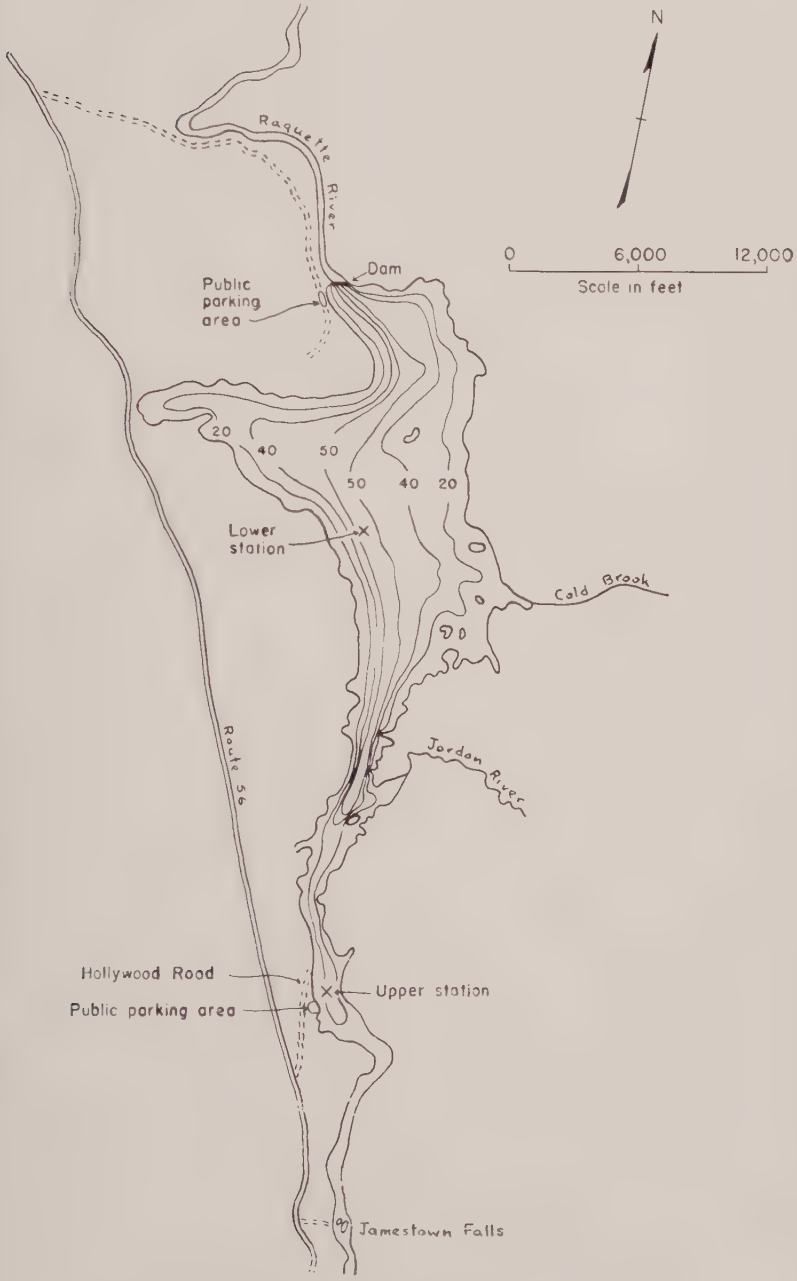

Figure 1. Map of Carry Falls Reservoir (Contours in feet.)

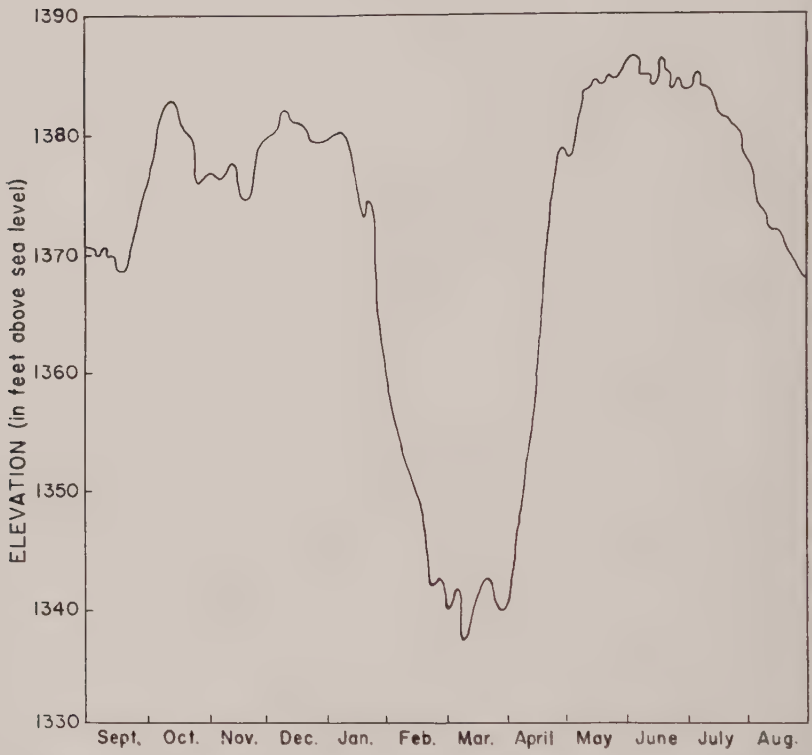

Figure 2. Water levels in Carry Falls Reservoir from September 1, 1954 to September 1, 1955.

lake, when full at an elevation of 1,385 feet, covered 3,200 acres and held about 5 billion cubic feet of water. It had a maximum width of over 2 miles, a maximum depth of over 60 feet, and approximately 25 miles of shoreline.

This project was constructed by the Niagara Mohawk Power Corporation for the purpose of storing water for use in generating hydroelectric power in its downstream plants. The operational plan called for impounding spring run-off for release during the low-flow summer and autumn months. Normally, maximum pool elevation would be attained in June and July, followed by a gradual 40-foot recession to minimum pool elevation in March. Figure 2 shows the trend in water levels from September 1954 to September 1955. Original river levels were reached in much of the impoundment area at times during the winter.

Actually, the impoundment did not raise water levels sufficiently in the upper mile of the river below Jamestown Falls to cause any major changes in the environment in that section. Although water levels fluctuated 2 or 3 feet in the Jamestown stillwater, these levels seemed to be influenced more by the volume of flow coming down the river than by the height of water existing at the dam.

Jamestown Falls still acted as a barrier to upstream migration of fish from the area; while Carry Falls dam, of course, stopped fish from entering (but not leaving) at the lower limit of the reservoir.

The barrier falls on the Jordan River and on Cold Brook were a short distance outside the impoundment area and so were not inundated when the reservoir was filled. Therefore, they continued to obstruct the upstream movements of fish at these points.

As water levels dropped in late summer in 1955, large areas of bottom were exposed to view. The bottom was composed mainly of gravel and sand, with boulders of varying size in some areas. In addition there were some flat areas where mud and muck predominated. It was presumable that little change had occurred in the original character of the soft bottoms of the stillwater sections. Bottom contours were very irregular. Low stumps, generally not over a foot high, studded large areas which had been cleared of forest cover before impoundment.

TEMPERATURES Air and water temperatures were fairly high during the abnormally hot, dry summer of 1955. There was a close relationship between temperature of the air and temperature of the surface waters of the reservoir. Early-afternoon temperatures (in degrees Fahrenheit) taken near the old Hollywood road access point averaged as follows:

	July		August	
	Air	Water	Air	Water
Minimum	69	77	62	71
Maximum	86	82	87	82
Average	79	79	76	76

The temperature of surface water near the dam was taken several times and found to be about the same as that near the old Hollywood road.

Partial thermal stratification developed in the deeper waters of the main body of the reservoir during the summer (Figure 3 and Table 5). At the lower station in late June there was little difference in water temperature between the surface and depths down to 20 feet. This upper layer of essentially uniform temperature constituted an

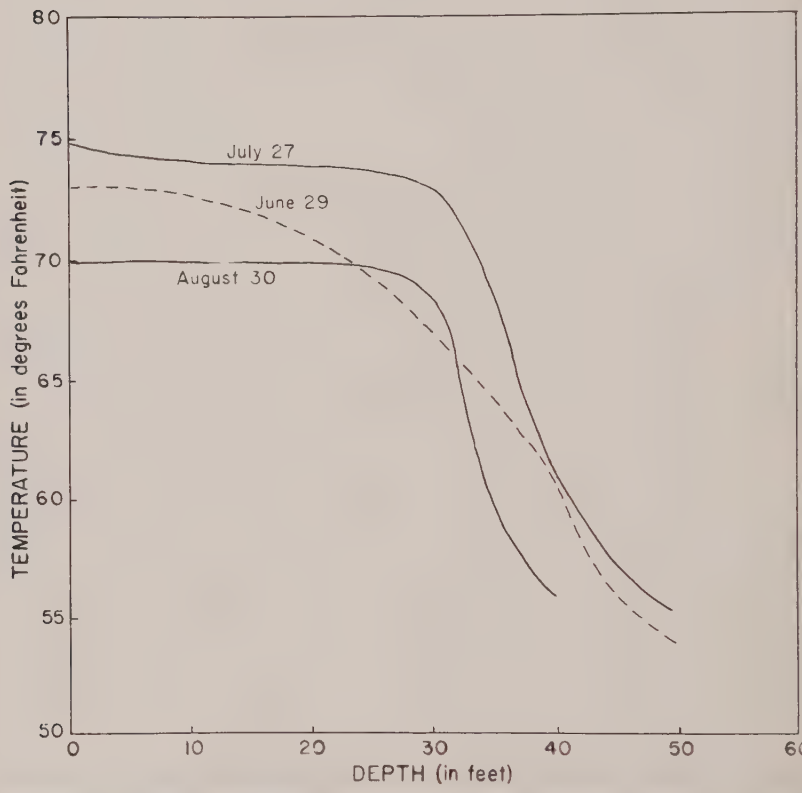

Figure 3. Water temperature at various depths at lower station on Carry Falls Reservoir during summer of 1955. Lower end of each curve represents bottom reading.

epilimnion. However, the temperature dropped rapidly from the 20-foot level all the rest of the way to the bottom, forming an area of rapidly falling temperature known as the thermocline. As the summer progressed, surface waters became warmed to a greater depth. However, thermocline conditions continued to exist at all times in depths below 30 feet. A lowermost layer of uniformly cold water, known as the hypolimnion, was never present during the period of study. The drawing-off of water through the deep-water penstocks at the dam during the spring may have interfered with the formation of a hypolimnion. Minimum bottom temperatures during the summer were fairly constant and remained in the vicinity of 55° F., which was not nearly as cold as ordinarily found in lakes where complete stratification occurred.

TABLE 5. WATER TEMPERATURES AND CONCENTRATIONS OF DISSOLVED OXYGEN AT VARIOUS DEPTHS AT TWO STATIONS ON CARRY FALLS RESERVOIR DURING THE SUMMER OF 1955

Location*	Depth in feet	June 29		July 27		August 30	
		Temperature in degrees Fahrenheit	Dissolved oxygen in p.p.m.	Temperature in degrees Fahrenheit	Dissolved oxygen in p.p.m.	Temperature in degrees Fahrenheit	Dissolved oxygen in p.p.m.
Lower station	0	73	8.0	75	8.0	70	6.4
	10	73	8.0	74	..	70	..
	20	71	8.0	74	..	70	..
	30	67	7.2	73	..	69	6.3
	35	..	..	69	3.6	60	trace
	40	61	6.0	61	..	56§	trace
	45	56	2.5	57	..	..	..
	50	54§	..	55§	0.0	..	..
Upper station	0	73	8.8	76	8.0	68	..
	10	70	..	75	..	67	..
	15	70	..	74	..	67§	6.8
	20	70	8.0	73	..	..	..
	25	66	6.4	71	4.0	..	..
	28	..	4.0	64§	0.8	..	..
	30	64§	..	..	..	..	..

* See Figure 1 for locations of stations.
§ Indicates bottom reading.

Relatively little evidence of thermal stratification was found at the shallower upper station. The summer drawdown had lowered water levels by late August to such an extent that the inflow of the river was causing complete mixing of the water at this point.

CHEMICAL FEATURES Chemical stratification occurred, in association with thermal stratification, during the summer months (Table 5). Concentrations of dissolved oxygen remained quite high at all times in the wind-mixed surface waters of the epilimnion. However, as the summer progressed, the supply of oxygen became depleted from the bottom upwards in the colder, stagnant waters of the thermocline. By the end of August, only slight traces were found at depths below 30 feet. Also, at this time a fairly strong odor of hydrogen sulfide was noted in water samples from near the bottom, but it lessened as the depth decreased and was absent above the thermocline.

Alkalinity (in p.p.m. $CaCO_3$) of the surface waters varied from about 11 on June 29 to 16 on August 30. Readings of pH were taken only on August 30, at which time they were 6.8 at the upper station and ranged at the lower station from 6.4 at the surface to 6.3 at 35 feet and 6.0 at the bottom in 40 feet of water.

The general color of the surface waters appeared to be light brown. However, on August 30 it was observed to be slightly greenish in samples from the thermocline area. Transparency was quite good.

Aquatic Vegetation Growths of aquatic vegetation were conspicuously absent in the main body of the reservoir. Only quillwort (*Isoetes*) was observed to be present, occurring on flats exposed by falling water levels in late summer. This plant is typical of zones of fluctuation in man-made reservoirs of the northeastern states.

Apparently normal growths of aquatic vegetation were found in the Jamestown stillwater, an area where relatively little fluctuation in water level was caused by the impoundment.

Fish Population

Information pertaining to the fish population was obtained by methods similar to those employed in 1951.

Composition, Abundance and Distribution In general, the same species of fish were present in the same relative abundance as during the preimpoundment study. However, some exceptions were found.

The most notable exception was a tremendous increase in numbers of bullheads. This species was abundant in 1955.

Two species recorded as present in 1951 were not found during the study in 1955. No brook trout were caught in the reservoir, and no blacknose shiners were observed or seined. It is worthy of note that, on a preliminary visit to Carry Falls Reservoir on July 15, 1953, large schools of this latter species were observed in shallow water. Probably this species was still present in 1955, although the fact that none were actually found indicated the numbers were small.

One additional species was recorded in 1955—the lake herring (*Leucichthys artedi*). Two specimens measuring 8.7 and 15.7 inches in length were taken on July 27 in a gill net set in 50 feet of water. This species had been present for many years in lakes (e.g. Tupper Lake) further upstream in the Raquette River drainage, so it may not have been entirely a newcomer to the area.

Most of the species were found to be generally distributed throughout the reservoir, except that very few northern pike were taken in the Jamestown stillwater area. The best catches of fish were made around the shoreline, or at least in sections of relatively shallow water, indicating possibly a greater abundance in these areas than in deep water. Although chemical conditions were extremely poor in deep water in midsummer, a catch consisting of 42 perch, 1 bullhead and 2 lake herring was made in a gill net set in 50 feet of water on July 27. Apparently some fish penetrated into the deepest water, although how long they may have remained there is not known.

It was not possible during the summer of 1955 to make a detailed investigation of the composition of the fish populations in the tributaries, the lower courses of which had been flooded by the impoundment. However, brook trout were still reported caught in Cold Brook. Also, no reports were obtained that any warm-water species such as bass, pike, perch, etc. had appeared in this stream or in the Jordan River above the falls.

GROWTH RATE Scale samples were used as before in determining ages.

Age-length data on smallmouth bass are given in Table 6. Older age groups were again poorly represented in the sample, but this does not necessarily mean that older bass were entirely absent from the reservoir. Actually, several bass measuring about 17 inches in length were reported caught; but unfortunately no scales were available from these fish, which were probably considerably older than those in the sample. In examining scales, it was observed that certain individual

TABLE 6. AGE-LENGTH RELATIONSHIP OF SMALLMOUTH BASS TAKEN BY ANGLING BETWEEN JULY 15 AND AUGUST 15 IN THE CARRY FALLS SECTION OF THE RAQUETTE RIVER IN 1951 AND 1955

Age group	1951				1955			
	Number of fish	Length in inches			Number of fish	Length in inches		
		Minimum	Maximum	Average		Minimum	Maximum	Average
II	1	..	..	7.9	3	6.5	8.2	7.1
III	5	7.4	9.8	8.9	10	8.7	12.3	10.7
IV	8	9.5	12.4	11.0	4	9.3	12.2	10.8
V	7	10.3	14.3	11.8	9	10.0	14.5	12.4
VI	3	12.6	12.9	12.1	7	10.0	14.5	12.4

fish exhibited an erratic growth pattern. Also, it was noted that some, but not all, bass exhibited continuous rapid growth during the preceding three years, the period of impoundment.

Nine pikeperch were collected on July 27 in a trap set about 2 miles below Jamestown Falls. Two were in their second year of life and measured 8.6 and 8.8 inches in length, respectively. The other seven were in their third year of life. They ranged from 10.7 to 12.9 inches in length, averaging 12.0 inches. A single specimen, taken by angling on September 5, was also in its third year and measured 14.9 inches. No large specimens were taken in 1955.

Reproduction No plantings of hatchery or other fish of any kind were made in the impoundment area at any time between the first filling of the reservoir in 1953 and the postimpoundment study in 1955.

Conditions in 1955 were good for detecting evidence of natural reproduction. The water was quite clear, facilitating observations.

Abundant evidence of good natural reproduction by smallmouth bass was found. Numerous schools of black fry guarded by adult males were seen around an island off the mouth of the Jordan River on June 17. The water temperature was about 70° F. at the time. Larger fry in considerable numbers were seen on June 29 scattered along a slightly submerged section of the old Hollywood road. Shore seining on July 27 at several widely-distributed points around the main body of the reservoir revealed that young-of-the-year bass were generally common.

There were very extensive areas of gravel bottom at many points around the reservoir which provided excellent spawning grounds for such species as smallmouth bass, rock bass and sunfish.

Young-of-the-year perch, bullheads, and fallfish were abundant in the vicinity of the Hollywood road access site on June 29. Young of these species were found to be common at the several points seined on July 27. Natural spawning was very successful for these kinds of fish.

Little or no evidence of natural reproduction by some of the other species was found. Only one young northern pike was collected. No young of the remaining species known to be present were collected or observed, although this might not have been true if it had been possible to make a more intensive search for them. For example, pikeperch probably reproduced successfully in the early spring in the rocky-bottomed, swiftwater sections found in the upper end of the impoundment area. No hatchery pikeperch fry had been planted in the

impoundment, yet 1- and 2-year-old fish were taken in net collection. These undoubtedly resulted from natural spawning.

Utilization In keeping with the requirements of the Federal license under which the project was constructed, full public utilization of the fisheries resource was permitted and even encouraged. The Niagara Mohawk Power Corporation constructed roads and two parking lots complete with ramps for boat launching, one at the dam and one just off the old Hollywood road towards the upper end of the reservoir. Falling water levels and a receding shoreline made the upper site unsuitable for launching boats during the latter part of the summer. However, Niagara Mohawk granted the public a permanent easement over the old Hollywood road, which had been abandoned by the Town of Colton, and this road continued to provide means of access throughout the summer.

Weather conditions during the summer of 1955 were generally good, and there were no unusual circumstances to affect fishing; so the fishing pressure was considered to be normal on the reservoir. Most of the fishing was done on weekends, about 50 per cent of the weekly fishing effort being expended on Saturdays and Sundays.

Data on effort and catch have been given in Tables 1 to 4. It was estimated that 656 angler cars were present at the reservoir during July and August. Of these, 372 (57 per cent) were actually seen and counted. Some 281 (43 per cent) were checked and found to contain a total of 666 anglers, or an average of about 2.4 anglers per car. The sample included in Table 1 amounted to about 28 per cent of the estimated total effort and catch by car anglers.

Further analysis of the available data provided additional information of interest and value. Approximately 73 per cent of the car anglers were men, 16 per cent women, and 11 per cent children. About 45 per cent of them fished from boats and 55 per cent from shore. They each fished 3.3 hours and caught 5 fish, on the average. Analysis of a sample consisting of 175 anglers on whom information was obtained regarding their home residence showed that many came from a wide area, although over half were of fairly local origin (Table 7).

Data on types of lures was not complete enough to determine their relative usage. However, certain types were undoubtedly more successful than others in taking certain species of fish. For example, 180 hours of fishing in August with minnows and artificial lures resulted in the taking of 14 smallmouth bass, 11 northern pike, and no bullheads. In

Figure 7. Distance* to Home Residence for Anglers Fishing in the Carry Falls Section of the Raquette River in 1951 and 1955

Year	Item	Miles from Carry Falls Reservoir within State					Out of State	Total
		0–20	21–50	51–100	101–200	Over 200		
1951	Number of anglers	49	13	8	83	42	19	214
	Per cent	23	6	4	39	19	9	100
1955	Number of anglers	102	18	10	39	6	0	175
	Per cent	58	10	6	22	4	0	100

*Straight-line distance.

this type of fishing, it required approximately 13 hours for catching one bass and 16 hours for one pike. During the same period, 168 hours of fishing with worms took 3 bass, no pike, and 693 bullheads—a rate of 56 hours per bass and ¼ hour per bullhead.

It should be mentioned that fishermen concentrating on gamefish (bass, pike, and pikeperch) were quite apt to discard many of the non-gamefish species. Thus, it is quite possible that the recorded catch of perch, rock bass, fallfish and sunfish may not have represented the true relative availability of these species to anglers. Reports as to numbers of these species returned to the water were not considered to be very reliable.

Some information was obtained relative to the proportion of sub-legal-sized specimens in the available populations of gamefish. On the basis of anglers' reports of small bass released, it appeared that about 40 per cent of all the bass caught were sub-legal in size. However, the proportion of short bass was much higher at the upper end of the reservoir. In the section below Jamestown Falls, about 70 per cent of the bass caught were undersized; while in the lower, main body of the reservoir, only about 20 per cent were undersized. Of all the northern pike caught, very few (about 3 per cent) had to be released because they were sub-legal in size. A few undersized pikeperch were reported thrown back.

DISCUSSION OF FINDINGS

The impoundment of the Raquette River at Carry Falls resulted

in significant changes in the environment, in the existing fish population, and in the utilization of the fishery resource. However, due to the limitations of the sampling methods used in these studies, only rather gross changes can be pointed out with any great degree of certainty.

The original river environment was replaced by a more complex set of conditions which ranged from river-like in late winter to lake-like during much of the rest of the year. The great fluctuation in water level during each year may have reduced the over-all fish-producing potential of the reservoir. This would result from the reduced volume of water, from interference with establishment of a lasting bottom fauna, and from possible losses of fish and forage downstream through the dam. However, such harmful effects would be offset to some extent by concentration of both fish and existing food organisms into the three stillwater sections of the river during periods of extreme draw-down. Thus, fish-eating species might benefit by having their food supply made more available to them during these periods. Also, the stillwaters would serve as sanctuary pools and help prevent losses which might otherwise occur through the dam.

One of the most striking changes noted in the environment was the disappearance of nearly all forms of rooted aquatic vegetation in the main body of the reservoir. Apparently the original growths of vegetation were drowned out when the dam was filled, except in the old Jamestown stillwater at the upper end of the reservoir. In view of the annual 40-foot fluctuation of water level, it appeared likely that very few kinds of rooted aquatics would become reestablished.

Another feature of the new, lake-like environment was the development of thermal and chemical stratification during midsummer in the deeper waters. Although a considerable volume of cold water was present, the oxygen content of this water became so low that it was unsuitable for occupancy by cold-water species such as trout. Also, the poor chemical conditions no doubt reduced the value of the deeper waters as a forage area for warm-water species.

Little evidence was noted of any increase in fertility due to impoundment. On a single preliminary trip to the reservoir in 1953, the first year the reservoir was full, a heavy bloom was observed in the shallow-water areas, indicating good fertility of the water. However, this initial fertility must have been of short duration, since the waters of the reservoir were generally very clear in 1955. The sandy, gravelly soil which formed much of the bottom of the reservoir appeared to be basically infertile.

Quantitative studies to determine the exact magnitudes of the populations of various species of fish in the area before and after impoundment were beyond the scope of the investigation. However, some general indications of relative abundance, or more accurately stated—relative availability to anglers, were obtained from the creel census.

Smallmouth bass and northern pike continued to be the most important and sought after game species throughout the reservoir. The quality of angling for these species, as measured in terms of average hours of fishing required to catch a fish, did not change significantly. About 11 hours were required to catch one bass both before and after impoundment, while the time required to catch one pike dropped slightly—from 35 to 32 hours.

Most of the other species of fish (including rock bass, yellow perch, sunfish and fallfish) were of secondary importance to anglers. Fishing for these species was poorer, if anything, following impoundment; although information on this point was not considered too reliable, in view of the fact that complete data were not available regarding fish of these species which may have been caught and returned to the water because they were undesirable to some anglers. However, there did appear to be a marked decrease in the number and size of fallfish taken following impoundment.

The one change of unquestionable significance in the fish population was the great increase in abundance of bullheads. In 1955 they constituted nearly 88 per cent of the total angling catch, as compared with about 3 per cent in 1951. Also, in 1955 it required, on the average, only about three-quarters of an hour to catch a bullhead, as compared to 96 hours in 1951. The average size of bullheads, however, had dropped from 10.2 inches in 1951 to 7.6 inches in 1955, and almost none of large size were taken in 1955.

There was little evidence of changes in growth rates for the other species of fish following impoundment. The average size of smallmouth bass taken had increased slightly (from 11.6 inches to 12.4 inches), but the age-length relationship as determined from rather limited samples (Table 6) showed only a slight increase in rate of growth. The northern pike taken by angling in 1955 averaged approximately the same length as in 1951. The sizes of the samples for other species were so small as to make the data of little value for comparisons.

The proportion of legal-sized bass to sub-legal-sized bass changed from about 1 to 3 in 1951 to about 1 to 1 in 1955. Presence of a high

proportion of small, young bass was noted in 1951 as being characteristic of the rapids sections of the river, and it was suggested that bass might be shortlived in the river environment. The presence of a higher proportion of older bass in the catch from the reservoir could mean that the survival rate did improve, thus lending support to this theory. However, the change in ratio could also mean a decrease in the rate of production of young bass or in their relative catchability under the conditions found after impoundment.

Natural reproduction by the various warm-water species existing in the area appeared to be successful enough to keep the reservoir adequately stocked. However, this generalization might not apply in the case of northern pike. Anglers reported throwing back very few (about 3 per cent) undersized pike, and young-of-the-year pike were not in evidence—all of which may indicate poor reproduction by this species. The weedy areas were mostly gone where pike may have spawned prior to the impoundment, and rapidly rising water levels in early spring when pike spawn may have had some adverse effect on the hatching of their eggs. Also, bullheads, which were present in large numbers, may have consumed considerable pike spawn.

Possibly northern pike might decrease in numbers eventually, but conditions were good for self-maintenance by the other game species present. The reservoir would normally be full and fluctuate little during the bass spawning season, so usually bass nests would not be harmed because of changing water levels. Pikeperch would have excellent spawning areas available towards the upper end of the reservoir, and it would be unlikely that rising water levels in these areas in the spring would harm their spawn. It was quite possible that pikeperch might increase in numbers in the reservoir in the future and become a more important item in the anglers' catch than previously.

Fishing pressure in the area was considered as being relatively light to moderate during both preimpoundment and postimpoundment periods. The reservoir continued to attract anglers from a wide area, although the percentage of anglers from nearby localities increased, possibly because these anglers were more aware of the existence of the new reservoir and interested in exploring its possibilities. The good bullhead fishing would also be an inducement for local anglers to return more often.

Means of access for the general public continued to be good and were even improved to encourage fishermen to use the new, man-made lake. However, it became more necessary for fishermen to bring their

own boats if they wanted to cover the entire area of the reservoir. The great decline in water level as the fishing season progressed discouraged any thought of establishing boat liveries.

The total fishing effort expended in the area, as represented by the total number of anglers and hours fished during July and August, was about four times as great during the postimpoundment study as during the preimpoundment study. However, because of unusual conditions in 1951, fishing pressure then was estimated to be only about half of normal. Therefore, the effort in 1955 may actually have been only about double what it would have been in a normal preimpoundment year.

The total estimated catch of fish in 1955 increased over that in 1951 by about 20 times in number and 10 times in weight. However, this increase was made up mainly of bullheads. The catch of gamefish species (bass and pike), on the other hand, continued to be roughly in proportion to the amount of fishing done.

The general quality of the fishing (except for bullheads) did not change greatly following impoundment. In 1951 each angler, on the average, fished 3.2 hours and caught 1 fish. In 1955 each angler, on the average, fished 3.3 hours and caught 5 fish; but over 4 of these 5 fish were bullheads.

CONCLUSIONS

The formation of Carry Falls Reservoir resulted in increased utilization of the area for fishing. At least twice as many fishermen were attracted to the reservoir as visited the same section of river during normal seasons before impoundment.

The catch of fish increased greatly following impoundment, due almost entirely to a marked expansion of the bullhead population. At the same time, the quality of fishing for the principal gamefish species (bass and pike) remained about the same—mediocre.

There appeared to be no damage to the original fish resource. Evidence as to possible invasion of tributary trout waters by warmwater species of fish from the reservoir was inconclusive; but it seemed likely that such penetration, with possible harmful effects, did not occur. Great fluctuation in water level during the course of each year was unavoidable because the primary purpose for which the reservoir was created was to store water and regulate its flow for maximum production of hydroelectric power. Probably this fluctuation limited both fish production and utilization to some extent, but both factors showed an over-all gain rather than a loss.

Natural reproduction appeared to be adequate for maintaining populations of desirable angling species, with no need for additional stocking of hatchery fish.

Existing laws as to open seasons, size and catch limits were considered to be satisfactory for regulating the fishing under the conditions found in the reservoir.

COMPARATIVE VALUE OF STOCKING THREE TYPES OF GAME FARM PHEASANTS[1]

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ABSTRACT

During the spring and fall of 1955 the Conservation Department made a large-scale test of one phase of pheasant stocking. Its primary objective was to determine which of three types of stock would produce, per dollar spent for propagation or purchase, the highest return to the hunter of birds of acceptable quality. The three types used comprised (1) State game farm birds released as half-grown juveniles, (2) State game farm birds held and released as adults, and (3) purchased adults. Test groups, all banded cocks, were released in a 250,000-acre block of the Lake Plains region and band returns from hunting during the open season were used as a basis for analysing the results.

The purchased adults gave the greatest return per stocking dollar. The birds released as half-grown young ranked second. The State game farm stock released as adults gave the best rate of return to the gunner, but the cost of these birds was very high as a result of heavy losses on the island used for holding them during the late summer and early fall. Hunters were well satisfied with the sporting quality of all three groups.

New York has a long tradition of pheasant stocking and, over the past half century, has developed one of the largest state-owned production systems in the country. This plant evolved during the many years when pheasant stocking was viewed as a "biological assist" needed to establish or build up breeding populations. The development of these facilities seemed justified since stock from private game farms of the era did not meet the standards considered necessary for such a program.

[1] A contribution of Federal Aid in Fish and Wildlife Restoration Project W-87-R.

All conceivable pheasant range in the State has been stocked, repeatedly, using the best quality birds that it was practical to produce. This strain has had ample opportunity to become established wherever the environment is favorable. Under these conditions, continuation of a large-scale release program must be viewed, basically, as stocking for the gun.

For some years, New York's game farms have been operated primarily to produce half-grown birds, of approximately equal sexes, for release during the summer. Band returns from test groups have been variable but generally low.

Recently, however, several other states have reported high returns from adult birds stocked just before the hunting season. In view of this, the Conservation Department undertook a large-scale test of one phase of pheasant stocking during the summer and fall of 1955. The study was not designed to answer the question: to stock or not to stock? Nor was it designed to assess the total cost of stocking. Rather, its primary objective was to determine which of three types of stock would produce, per dollar spent for propagation or purchase, the highest return to the hunter of birds of acceptable quality. The three types used comprised (1) State game farm birds released as half-grown juveniles, (2) State game farm birds held and released as adults, and (3) purchased adults.

Both groups of State game farm stock involved birds produced and reared in the usual way until about 8 weeks of age. At this time some were released directly on a study area and the others were transferred to an island where they were held under semi-wild conditions until just before the hunting season. The latter were then trapped and part of them were released on the study area. Both groups included two lots representing different hatches, about a month apart, on the farms. The purpose of rearing one group for an additional period on an island was to test this procedure as a means of improving the hardiness and sporting qualities of the birds. An island was used in lieu of covered holding pens on the game farms.

The purchased stock was obtained from private game farms and was released on the study area at essentially the same time as the island-reared birds.

In all cases only cock birds were used. All those released on the study area were banded to permit analysis of records obtained for birds bagged during the hunting season. Most of the birds received bands carrying code letters only. This greatly simplified record keeping, par-

Figure 1. Map of New York State showing location of study area and Grenadier Island.

ticularly on birds sent to the rearing island and later retrapped. However, serially-numbered bands were used on samples of most test lots. This made it possible to compare band returns for stock from different farms and also served as a check on bias in interviews regarding hunter satisfaction in the event hunters or checkers deciphered the code.

The study area selected for release and harvest of the test birds was a 250,000-acre block of the Lake Plains region (Figure 1). It included most of Orleans County plus fringes of Niagara and Genesee Counties—all excellent pheasant range.

For the extended holding of part of the game farm stock, Grenadier Island in northeastern Lake Ontario was chosen. Roughly 1,300 acres in extent, this island lies about 4/5 mile from the mainland. Most of the area remains in old-field grassland although a few mature woodlots and patches of shrubs occupy wetter locations. Soils are generally shallow, overlying bedded limestone. While several dwellings remain, there are no full-time residents and there has been no active agriculture for a decade.

Prior to the transfer of pheasants to Grenadier Island, a 10-day trapping effort removed 7 foxes and 22 raccoons, but at least one fox

and several raccoons still remained when the birds arrived. An extensive pole-trapping program was set up early in the rearing period but woodlots and hedgerows provided an abundance of safe perches for raptors frequenting the vicinity.

REARING OPERATION ON GRENADIER ISLAND

Between June 28 and July 6, a total of 10,000 banded half-grown pheasants were transferred from State game farms to Grenadier Island. The second rearing cycle on the game farms provided 9,791 similar birds from August 9 to 26. The birds were liberated at a variety of sites scattered over the island. Following an early feeding of 1,400 pounds of grain, those of the first lot were left to fend for themselves since natural food appeared adequate to meet their needs temporarily. After addition of the second lot, observations indicated that the birds were not developing normally because of malnutrition. Thereafter, irregular feedings were made totaling about 16 tons of mixed grain.

The birds held on Grenadier Island suffered heavy losses during their stay. Mammalian predation was an important factor and its toll was increased by that of several great horned owls as well as by hawks migrating during the fall. An outbreak of botulism on a portion of the island was a secondary drain, and numbers of birds also were lost attempting over-water flights.

During most of this period, no special effort was made to determine the extent or causes of pheasant mortality. The holding phase was considered an extension of game farm operations rather than a research study, and only moderate, expected mortality was noted by those tending the birds.

In mid-August, however, a few birds were observed showing evidence of toxemia. After increasing numbers were found in early September, Department technicians were called in to make a field investigation. It was found that losses from botulism were occurring on about 200 acres at the eastern end of the island. Transmission of botulism toxins to healthy birds, as a result of their eating maggots or flesh from contaminated remains, was experimentally demonstrated. Evidence of heavy, previously undetected predation losses also came to light. With botulism present, and an abundant supply of decomposing, fly-blown pheasant remains to feed an epidemic, it was obvious that only a sharp drop in temperature or intensive field sanitation by removal of dead birds would reduce incidence of the disease.

The weather stayed warm. By mid-September botulism losses

showed a substantial increase, and a detail of fieldmen was dispatched to try to arrest the outbreak by removing dead birds. First priority was given the outbreak area by then somewhat enlarged over the early September focus. As a precautionary measure, careful searches were made considerably beyond the area where losses from toxemia were recognized. In three days of intensive work about 1,450 pheasants, dead from all causes, were picked up and cremated. While the weather remained unchanged, losses from botulism virtually ceased.

With the marked dropoff in losses from poisoning, several of the crew were released and the rest continued the search until approximately a quarter of the island had been covered. In the course of these searches, several strips were re-run more intensively and at a slower pace immediately after the first coverage. Additional birds were recovered on each repeat strip and averaged slightly less than 10 per cent of the number picked up the first time over.

During the early-September field investigation and the more extensive searches of mid-September, 2,544 dead pheasants were recovered. Of these, 1,782 remains showed evidence of violent death from predation, drowning or accident. The other 762 remains were found in and around the botulism outbreak area and showed no gross evidence of injury; presumably most had died of disease. To this group must be added some 400 more victims of disease found between mid-August and mid-September by workmen employed on the rearing island. While the feed-consumption data indicated a remaining population of 10,000 to 15,000 birds, or a mortality of 5,000 to 10,000, the survey findings, when projected, indicated that by mid-September some 9,000 birds had died. Of this total, botulism losses were calculated at about 1,200 (Table 1).

The relative importance of birds and mammals as predators of the young pheasants held on Grenadier Island was not established by the survey. While numbers of pheasants had been killed by owls (decapitated) or mammals (skull crushed or neck broken) and then left untouched, time did not permit analysis of most remains. Based on plumage and skeletal development, it was apparent that a majority had been lost shortly after their transfer to the island. In the interval before the survey, remains had been disturbed, dismembered, moved, buried, dug up, or scavenged.

In addition to mortality on the island, other pheasants were lost by escape or drowning. Neither the magnitude nor the time of this loss could be determined. Bands were returned from 39 birds of the older

Table 1. Projection of Pheasant Losses on Grenadier Island

Item	Number of birds
Mortality ascribed to "violent death"	
Remains tallied (¼ of island covered)	1,782
Correction for remains overlooked (10 per cent)	178
Subtotal	1,960
Correction for sample size	×4
Total	7,840
Mortality ascribed to "passive death"	
Remains tallied (entire outbreak area covered)	762
Correction for remains overlooked (10 per cent)	76
Diseased birds picked up by island workers	400
Total	1,238

group that were taken by hunting after flying half a mile to Fox Island. Three additional birds from this group were reported taken on the mainland during the hunting season.

Not all pheasants attempting flights from Grenadier Island were successful. About 20 drowned birds were found washed up on Fox Island during the summer. Similarly, letters were received reporting the bands of drowned "Grenadier" pheasants washed up on shorelines in a 180-degree arc from the rearing island. This area included all nearby land areas wave-washed from the direction of Grenadier Island. Since most of these shorelines are undeveloped farmland, the likelihood of such remains being found was low. In the course of the sanitation work on Grenadier Island, 26 drowned pheasants were found on the stretches of shoreline that were covered.

Pheasant retrapping on Grenadier Island was started in early October and 4,350 birds (3,477 of the first lot, 866 of the second lot, and 7 with no band) were recovered during about a 2-week interval. By the end of that time trapping success had dropped too low to justify further efforts. It is believed that, at most, only a few hundred birds then remained on the island.

STOCK RELEASED ON STUDY AREA

As has been mentioned, coincident with the transfer of half-grown pheasants from State game farms to Grenadier Island, identical stock was released directly on the study area. The two lots involved totalled 4,965 birds and were considered the control group.

Of the birds held on Grenadier Island and then retrapped, 2,879[2] were released on the study area between October 10 and 14.

The 4,950 purchased birds were received and released on the study area between October 10 and 22.

By making repeated use of about 100 release locations, each test lot was uniformly distributed over the study area. This overlay served to cancel out the effects of local differences in hunting pressure; each group was exposed to the same *total* hunting pressure. The stock released on the study area is summarized in Table 2.

TABLE 2. SUMMARY OF PHEASANT STOCK RELEASED ON STUDY AREA

Source	Number of birds	Age when released	Period of release
State game farms			
Released directly on study area	2,488	juvenile	June 28-July 6
	2,477	juvenile	August 9-23
Held for interim period on Grenadier Island	2,879	adult	October 10-22
Private game farms	4,950	adult	October 10-14

HUNTING RETURNS

No specific publicity program accompanied this experiment. The study area, lying near the metropolitan districts of Buffalo and Rochester, was selected primarily on the basis of having hunting pressure adequate to secure a significant harvest of test birds. Prior to the time when the birds were released, some 30 per cent of the land had been posted by landowners against trespass. It seemed probable that while publicity would increase band returns, it might also attract additional hunters. This, in turn, might trigger more posting.

In 1955 the pheasant season in the Lake Plains section ran for 12 days—October 24-29 and October 31-November 5. Throughout

[2] The remainder of the 4,350 retrapped were used to fulfill commitments to field trials and for stocking in northern New York.

the season an average of about 25 Department men were stationed on and about the study area to obtain band returns and to determine hunter satisfaction with the test birds. These men made field interviews, placed prepaid questionnaires on hunters' cars, and operated checking stations where main roads leave the area. Other returns were obtained by leaving self-service report boxes at business places and by interviewing landowners at their homes. Voluntary returns, reported directly to the Department, further increased the sample.

As of March 31, 1956, a total of 2,747 birds from the stock released had been reported taken by legal hunting (Table 3). A

Table 3. Summary of Returns From Legal Hunting on Study Area

Type of stock	Number stocked	Returns	
		Number	Per cent
State game farm birds released directly on study area	4,965	582	11.72
State game farm birds held on Grenadier Island	2,879	854	29.66
Birds purchased from private game farms	4,950	1,311	26.48
Total	12,794	2,747	21.47

majority of these band returns were tallied by Department checkers during the hunting season. Only a small proportion of the special report cards left on hunters' cars were filled out and returned, yet this source contributed nearly 25 per cent of the total band returns.

COST

The cost of pheasants produced on New York State game farms has not been accurately determined since the mid-40's except at the Ithaca Game Farm. Using the Ithaca figures as a baseline and adjusting upwards to account for somewhat higher costs on other farms, the Propagation Unit estimates that the maximum charge for the half-grown pheasants delivered to the study area or to Grenadier Island in 1955, should be about $1.50 per bird.

Final accounting of the costs of holding birds on Grenadier Island was based on assignment of "fair charges" for items of equipment, supplies, and services involved in the rearing operation. Charges for

small equipment and durable supplies were based on depreciation over the expected period of useful life. Items of major equipment such as jeeps and tractors were depreciated at 10 per cent. The rate paid for temporary labor was $10.56 per day. Work performed on the island by various regular employees of the Department was charged at the labor rate regardless of their actual salaries, with one exception. The time of the assistant game farm foreman who had nominal supervision of the island operation was charged at his actual salary rate.

This method of accounting reduced the total cost of some $47,000 for the Grenadier Island phase of the project to a figure of $19,800 as the charge for the rearing operation in 1955. The initial value of the stock transferred there from State game farms was $29,686.50 (19,791 birds at $1.50 each). Thus the aggregate value of these birds at the time of release in the fall was $49,486.50. Since only 4,350 were retrapped, the charge per bird released on the study area was $11.38.

The birds purchased from private game farms were delivered to the study area at an average price of $3.19 each.

The returns from legal hunting for each type of stock have been given in Table 2. Since the price of the purchased birds was the most definite cost figure at hand, its ratio to the percentage return for this group was used as a baseline. From this ratio the returns for the other groups were used to calculate the break-even prices—maximum prices that could be paid for equal stocking efficiency. Naturally, a relatively high band return would justify a proportionally higher cost per bird stocked. The resultant figures are given in Table 4.

TABLE 4. CALCULATED BREAK-EVEN PRICES COMPARED TO THE ACTUAL COSTS FOR THE THREE TYPES OF PHEASANT STOCK TESTED

Type of stock	Percentage taken by hunting	Calculated break-even price	Actual cost per bird stocked
State game farm birds released directly on study area	11.72	$1.41	$1.50
State game farm birds held on Grenadier Island	29.66	3.57	11.38
Birds purchased from private game farms	26.48	3.19	3.19

It is evident that the purchased adults used in this test gave the greatest return per stocking dollar. The young birds released on the

study area directly from the game farms during the summer ranked second, being about a 6 per cent less efficient method of stocking (cost *vs.* break-even price).

The birds reared to adulthood on Grenadier Island before being released on the study area, although giving the highest rate of return, were still too expensive in comparison with either of the other test groups. It should be noted that the high cost of this stock reflected the high losses during the free-range rearing period, for only 22 per cent of the birds shipped to the island were retrapped. A 70 per cent recovery would have been required to lower the cost to the break-even price.

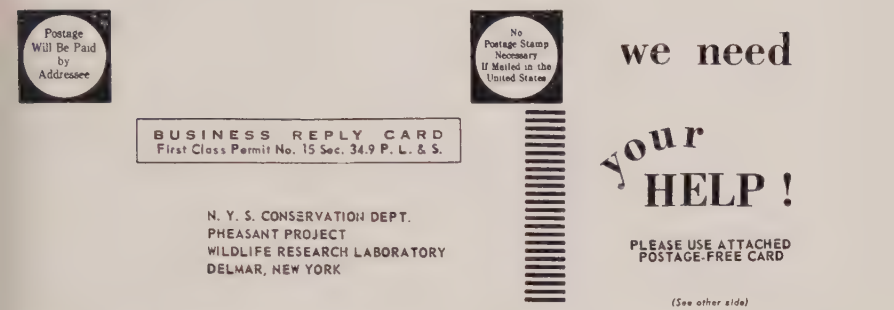
HUNTER SATISFACTION

In addition to cost, the factor of hunter satisfaction must also be considered in evaluating the results of such a test of pheasant stocking. To this end, technicians checking hunters questioned them as to the wildness and vigor of each banded bird they had taken. These interviews covered several behavior and condition characteristics of particular interest to the Department in its concern for quality as well as quantity of stocked birds in the bag. The system of coded bands and hopscotching band series, employed when the stocking was done, hid the identity of most banded birds from checkers as well as hunters and served to prevent bias in the interview data. For comparative purposes, similar data were recorded for a sample of the unbanded birds taken.

The special report cards (Figure 2) that were left on the cars of hunters who were afield carried the same "Banded Pheasant Data" questions that were used in interviews. Many of the cards that were returned also supplied similar information for the unbanded birds taken.

Hunters' replies to the behavior and condition questions indicated that, in these respects, no significant differences between the three types of stock had been observed. Slightly more than half the birds reported on in each group had "to be chased to make . . . [them] flush": slightly less than half ran "far" before flushing. Nearly every banded bird was reported to have flushed strongly and flown well, and to have been well-feathered and in good flesh.

Rather surprisingly, it was found that the reports, when subjected to testing, indicated that hunters who had taken released stock and those who had taken wild (unbanded) birds saw no significant differences in sporting quality between them. This was further substantiated by a number of hunters who had taken mixed bags. Several were sur-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No Postage Stamp Necessary If Mailed in the United States
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your
HELP !
BUSINESS REPLY CARD
First Class Permit No. 15 Sec. 34.9 P. L. & S.
N. Y. S. CONSERVATION DEPT.
PHEASANT PROJECT
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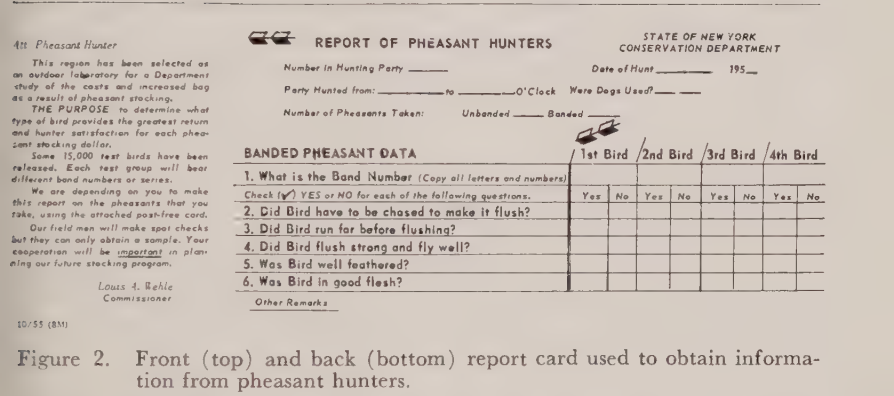
Att Pheasant Hunter
This region has been selected as an outdoor laboratory for a Department study of the costs and increased bag as a result of pheasant stocking.
THE PURPOSE to determine what type of bird provides the greatest return and hunter satisfaction for each pheasant stocking dollar.
Some 15,000 test birds have been released. Each test group will bear different band numbers or series.
We are depending on you to make this report on the pheasants that you take, using the attached post-free card.
Our field men will make spot checks but they can only obtain a sample. Your cooperation will be important in planning our future stocking program.
Louis A. Wehle
Commissioner
10/55 (8M)
REPORT OF PHEASANT HUNTERS
STATE OF NEW YORK
CONSERVATION DEPARTMENT
Number In Hunting Party
Date of Hunt 195
Party Hunted from: to O'Clock Were Dogs Used?
Number of Pheasants Taken: Unbanded Banded
BANDED PHEASANT DATA
1st Bird 2nd Bird 3rd Bird 4th Bird
1. What is the Band Number (Copy all letters and numbers)
Check (✓) YES or NO for each of the following questions.
Yes No Yes No Yes No Yes No
2. Did Bird have to be chased to make it flush?
3. Did Bird run far before flushing?
4. Did Bird flush strong and fly well?
5. Was Bird well feathered?
6. Was Bird in good flesh?
Other Remarks

Figure 2. Front (top) and back (bottom) report card used to obtain information from pheasant hunters.

prised to discover a band when they displayed their birds for a checker. Others, reporting by mail, stated that they saw no difference in behavior or condition between the native and the released birds.

Opinions expressed by hunters who had taken stocked birds were predominantly favorable. A number who mailed their reports added notes commending the Department on the quality of the test birds. Such expressions of hunter satisfaction involved birds from each of the major test groups roughly in proportion to the reported take for each group. It was apparent that the average hunter was well satisfied with the quality of all released stock. Thus, the factor of hunter satisfaction in no way modified the evaluation of the test groups based on cost-return ratios.

CONCLUSIONS

The adult pheasants purchased from private game breeders at an average price of $3.19 each showed the greatest stocking efficiency under the conditions of this test. State game farm stock released as half-grown young ranked second showing about 6 per cent lower

efficiency at the assumed cost of $1.50 each. Birds liberated on the study area after transfer from the rearing island showed the highest hunting return, but the combination of operational overhead on the island and high mortality during the birds stay there produced a prohibitive ($11.38) unit cost figure. Hunters were equally well satisfied with the sporting qualities of the birds from each of the three test groups.

The above rankings, while valid for the 1955 test, do not alone justify a radical departure from current pheasant propagation policy. The band returns from the field study appear to constitute an adequate and representative sample, and as such should accurately portray the proportional hunting take from the three test groups. However, the quality of birds in such groups may be expected to show considerable variation between years and sources and, in turn, might cause a significant change in proportional band returns on another occasion. Moreover, several of the cost figures might be subject to considerable change under a continuing operation.

The free-range rearing test on Grenadier Island should be considered wholly experimental. It now seems evident that to have a prospect of success, this technique would require a degree of predator control similar to regular game farm practice. Perhaps more feeding should have been practiced also, for food scarcity may well have stimulated dispersal and thus increased losses from drowning and escape. It should be emphasized, however, that any further trial of island rearing will risk a more severe disease outbreak than was experienced in 1955. Some infectious poultry diseases are most easily controlled by medication administered in the drinking water. An insular rearing site limits mass medication to drugs or agents that may be offered in combination with artificial feed. If the island affords a significant amount of natural feed, the problem of disease control becomes increasingly difficult.

ASPECTS OF THE EARLY LIFE HISTORY OF THE STRIPED BASS (*ROCCUS SAXATILIS*) IN THE HUDSON RIVER[1]

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ABSTRACT

The spawning grounds of the striped bass in the Hudson River in 1955 were found to include the area from Bear Mountain upriver to Cruger Island. On the basis of evidence collected, the most intense spawning took place in the vicinity of West Point in essentially fresh water. Striped bass eggs were found from mid-May through mid-June. The distribution and growth of young striped bass in the Hudson is described. The brackish portion which includes the area from Newburg south to the George Washington Bridge was found to be the most important nursery ground.

In an effort to develop sound management techniques for populations of striped bass along the Atlantic coast, a program of coordinated interstate research was undertaken. As part of this coastwise study, investigations were initiated in New York during 1954. In part, the objectives of the present study in New York included the delineation of the area utilized, as well as the conditions existing, during striped bass spawning, and the distribution and abundance of young striped bass. It is these aspects of the current program that are reported on here.

Raney (1952) summarized the available information on fluctuations in abundance and "dominant year-classes". Since a given year may have an important effect on the stock available to the fishery, it has become increasingly important to understand various phases of the early life history of the striped bass.

The fact that striped bass spawn in the Hudson River was established previously, but few specific data have been available. Curran and Ries (1937) reported numbers of young striped bass from the Hudson River. Greeley (1937) surmised that the spawning period included May.

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[1] A contribution of Federal Aid in Fish and Wildlife Restoration Project F-10-R. The authors are indebted to Dr. Edward C. Raney, Cornell University, who offered much helpful advice and, in particular, confirmed the identification of larval striped bass. Acknowledgment is also due to Gerald B. Talbot, U. S. Fish and Wildlife Service, through whose efforts a vessel was made available to the project, and to John Parkin, also of the U. S. Fish and Wildlife Service, who captained the vessel during the study.

METHODS

In planning field operations, the results obtained by other workers, both locally and in other sections of the country, were a great aid. However, the nature of the area and the desired objectives required that allowances be made for various conditions encountered. Following are the procedures that were adopted.

Spawning Ground Survey

The F.W.S. 1227, a 36-foot vessel, was made available from early May until late June, 1955. Six cruises were made, encompassing an area extending from Piermont north to Coxsackie, a distance of approximately 80 nautical miles. Sampling stations were spaced throughout this area at intervals, varying up to 10 miles apart. These stations are referred to in this paper by numbers which designate their distances in nautical miles above Yonkers, the base of operations (Figure 1). Plankton collections, totalling 285, were made between May 10 and June 22, 1955.

Two types of plankton-collecting gear were employed during the survey. Most widely utilized were half-meter plankton nets constructed of nylon netting designed to retain objects 1 millimeter or larger in diameter. In most instances two nets were towed simultaneously for 20-minute periods; one net was at the surface, and a second was from 12 to 18 feet below the surface. At some of the stations the nets were anchored to a buoy line and fished by tidal action. The other gear used was a small trawl (Figure 2) mounted on runners which was towed along the bottom at selected stations. The use of this trawl was restricted to sand or mud bottom less than 35 feet deep.

Surface temperatures were recorded throughout the sampling period. Water samples were collected from brackish water areas and were later titrated in the laboratory for salinity in parts per thousand of sodium chloride (NaCl).

Throughout this paper, data will refer to cruises, all in 1955, which are specified by Roman numerals. The period of each cruise was as follows:

Cruise I	May 16-May 20
Cruise II	May 23-May 27
Cruise III	May 31-June 3
Cruise IV	June 7-June 10
Cruise V	June 14-June 17
Cruise VI	June 20-June 22

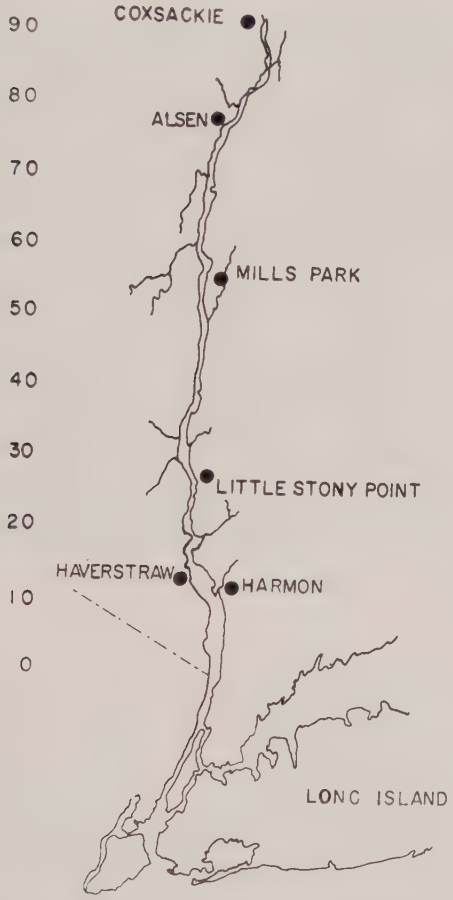

Figure 1. Map of Hudson River. Black circles represent the location of seining stations for quantitative sampling of juvenile striped bass in 1955. Figures to the left indicate the distance in nautical miles above Yonkers.

The eggs and early larval striped bass were identified by comparison with specimens obtained from the Weldon, North Carolina, striped bass hatchery. Early post-larvae of 12 to 14 millimeters were identified by the structure of the anal fin, which at this stage shows the development of spines characteristic of the striped bass. Stages intermediate in size between the early larvae and the post-larvae of 12 to 14 millimeters were identified by comparison with the known specimens on hand. The descriptions and illustrations provided by Pearson (1938) proved to be valuable and were constantly referred to.

Figure 2. Bottom trawl. This gear proved to be effective in the collection of early post-larval striped bass.

Collection of Juvenile Striped Bass

During the summer and early fall of 1954 exploratory seining for young and yearling striped bass was conducted in the Hudson River from the vicinity of Yonkers upriver to Coxsackie. Various environments were sampled using 10-, 25-, and 60-foot seines. Utilizing experience gained during 1954, an attempt at quantitative sampling for young striped bass was undertaken during the summer of 1955. Six stations were selected as being representative of the river. These were located at Harmon, Haverstraw, Little Stony Point, Mills State Park, Alsen, and Coxsackie which are indicated on the map of the Hudson (Figure 1). Each station was seined for 20 minutes using a minnow seine the specifications of which were as follows: hung 25 feet long by 7 feet deep in the center, tapered on the bottom to 5 feet deep at each end, ½-inch stretched mesh, 20/6 cable throughout. The 25-foot seine was employed because of the facility with which it could be handled under the variable conditions encountered at each site. Seinings were made at each station eight times throughout the summer with 2-week intervals between successive attempts. The young striped bass collected were preserved and later measured and counted. Temperature and salinity data were recorded at each seining location.

RESULTS

The authors feel that the findings of the studies under discussion were adequate to satisfy the objectives undertaken. It is hoped that the results as presented here will aid future workers in carrying on programs of a similar nature.

SPAWNING

A total of 71 striped bass eggs were recovered from collections made during Cruises I, II, III, and V. These cruises covered the period between May 16 and June 17. Numerous eggs from species not included in the present study were also found in the collections. Additional sampling was undertaken downriver from Iona Island prior to Cruise I, but no striped bass eggs were taken from this location at this time or later.

TABLE 1. DISTRIBUTION, BY CRUISE AND STATION, OF STRIPED BASS EGGS TAKEN IN THE HUDSON RIVER IN 1955

Station	Miles above Yonkers	Cruise						Total by station	Per cent of total
		I	II	III	IV	V	VI		
Yonkers	0.0	*	*	*	*	*	*	..	..
Nyack	8.0	..	..	..	..	..	*	..	..
Ossining	12.0	..	..	..	..	..	..	..	..
Croton Point	13.7	..	..	..	..	..	..	..	..
Stony Point	19.1	..	..	..	..	..	*	..	..
Iona Island	24.1	1	..	..	..	..	..	1	1.4
Lady Cliff	28.0	26	..	*	..	..	*	26	36.6
Worlds End	29.6	11	..	2	..	..	..	13	18.3
Bannerman's Island	33.6	..	..	..	..	7	..	7	9.9
Denning Point	35.6	..	16	1	..	..	..	17	24.0
Wappinger Creek	42.0	..	1	..	..	..	..	1	1.4
"B" Buoy	48.0	1	..	..	..	..	..	1	1.4
Crum Elbow	53.6	..	2	..	..	..	..	2	2.8
Indian Kill	57.6	..	2	..	..	..	..	2	2.8
Rondout Creek	62.0	..	..	..	..	..	..	..	..
Cruger Island	69.1	..	1	..	..	..	..	1	1.4
Alsen	76.3	..	..	..	..	..	..	..	..
Athens	84.0	*	..	*	*	..	..	..	..
Four Mile Point	87.1	..	*	..	..	*	*	..	..
Coxsackie	90.2	*	..	..	..	..	..	..	..
Total by cruise		39	22	3	..	7	..	71	XXX
Per cent of total		54.9	31.0	4.2	..	9.9	..	XXX	100.0

* No sample taken.

Of the total striped bass eggs collected 64, or 90.2 per cent, were taken from an area extending from Iona Island (mile 24.1) upriver to Denning Point (mile 35.6); the remaining 7 eggs were collected from various points upriver to Cruger Island (mile 69.1). The distribution of eggs recovered, by cruise and station, is shown in Table 1.

The area of the river from which most of the striped bass eggs were collected is relatively narrow, with moderate to swift current, and has depths ranging up to 200 feet. The relationship of brackish water areas to striped bass spawning in the Hudson is clearly demonstrated by the data given in Table 2. Surface salinities at the stations where

Table 2. Surface Salinity (in parts per thousand) at Selected Stations on the Hudson River in 1955

Station	Miles above Yonkers	Cruise					
		I	II	III	IV	V	VI
Croton Point	13.7	2.50	3.20	2.40	3.50	2.90	3.20
Stony Point	19.1	1.70	1.40	0.90	1.22	1.70	1.90
Iona Island*	24.1	0.80	0.48	0.20	0.26	0.50	1.00
Worlds End	29.6	§	0.25	§	§	§	0.20
Denning Point	35.6	§	§	§	§	§	§

* Indicates farthest point downstream from which striped bass eggs were taken.

§ Denotes salinity of less than 0.1 p.p.t.

striped bass eggs were recovered were, in all cases, one part sodium chloride per thousand or less. The surface salinity of the river downstream from the locality where eggs were found rose sharply. In addition to surface salinities, subsurface samples were also taken at some of the stations. In general, the subsurface values were not very much greater than those found at the surface.

Surface water temperature of the river between Croton (mile 13.7) and Alsen (mile 76.3), during the cruise period, increased from a mean of 60.6° F. for Cruise I to 72.6° F. in the course of Cruise VI. Surface temperature at stations from which striped bass eggs were collected varied from 59° to 68° F. Table 3 includes surface water temperature observations between Croton Point and Alsen for the period during which cruises were being carried on.

Larval Striped Bass

Larval and early post-larval striped bass were found to be readily available to the collecting apparatus utilized. During the spawning

TABLE 3. OBSERVED SURFACE TEMPERATURES (IN DEGREES FAHRENHEIT) AT SELECTED STATIONS ON THE HUDSON RIVER IN 1955

Station	Miles above Yonkers	Cruise I		Cruise II		Cruise III		Cruise IV		Cruise V		Cruise VI	
		Temperature	Time*	Temperature	Time*	Temperature	Time*	Temperature	Time*	Temperature	Time*	Temperature	Time*
Croton Point	13.7	65	**1:26**	65	**3:30**	66	**11:43**	65	**1:15**	72	**12:13**	74	**1:02**
Stony Point	19.1	60	**11:50**	64	**11:54**	65	**12:52**	67	**12:18**	68	**12:35**	71	**1:40**
Iona Island	24.1	59	**1:00**	64	**12:44**	64	**1:54**	67	**1:22**	67	**1:36**	70	**2:14**
Worlds End	29.6	60	**2:08**	66	**1:34**	65	**3:01**	67	**1:55**	67	**2:43**	70	**3:16**
Denning Point	35.6	60	**3:14**	67	**2:28**	66	**4:08**	67	**2:50**	68	**3:46**	75	**4:26**
Wappinger Creek	42.0	59	**4:42**	68	**3:26**	67	**5:34**	67	**3:43**	68	**5:01**	74	**5:44**
"B" Buoy	48.0	60	**5:43**	67	**4:25**	66	**6:38**	68	**4:43**	67	**6:00**	71	**6:54**
Crum Elbow	53.6	60	**6:35**	66	**5:22**	67	**7:28**	67	**5:47**	67	**6:50**	75	**8:00**
Indian Kill	57.6	59	7:08	66	**6:12**	67	8:00	68	7:33	68	7:45	71	8:25
Rondout Creek	62.0	59	8:00	66	7:55	68	8:54	69	8:39	69	8:35	73	9:30
Cruger Island	69.1	62	9:00	67	9:17	68	9:56	69	10:02	70	9:42	73	10:50
Alsen	76.3	64	10:00	69	10:38	69	11:00	69	11:26	70	10:43	76	12:00
Average		60.6	xxx	66.3	xxx	66.5	xxx	67.5	xxx	68.4	xxx	72.8	xxx
Maximum		65	xxx	69	xxx	69	xxx	69	xxx	72	xxx	76	xxx
Minimum		59	xxx	64	xxx	64	xxx	65	xxx	67	xxx	70	xxx

*Blackface type indicates "p.m." time; lightface, "a.m." time.

ground survey, 532 of these fish were captured. Larvae of other species, predominantly clupeid fishes, were abundant.

The mean total length of the larval and early post-larval striped bass increased from 4.2 millimeters during Cruise I to 9.2 millimeters in the course of Cruise VI.

The distribution of larval and early post-larval striped bass by cruise and station is shown by Table 4. Although subsurface plankton

Table 4. Distribution, by Cruise and Station, of Striped Bass Larvae and Early Post Larvae Taken in the Hudson River in 1955

Station	Miles above Yonkers	Cruise						Total by station	Per cent of total
		I	II	III	IV	V	VI		
Yonkers	0.0	*	*	*	*	*	*	..	..
Nyack	8.0	..	..	..	..	..	*	..	..
Ossining	12.0	..	..	..	..	1	..	1	0.2
Croton Point	13.7	..	..	..	2	..	5	7	1.2
Grassy Point	16.0	..	..	..	*	2	16	18	3.1
Stony Point	19.1	..	..	..	..	5	*	5	0.9
Peekskill Bay	23.0	..	*	*	61	..	2	63	10.8
Iona Island	24.1	..	..	11	13	93	..	117	20.0
Lady Cliff	28.0	..	5	*	25	2	*	32	5.5
Worlds End	29.6	..	..	7	5	14	3	29	5.0
Bannerman's Island	33.6	..	..	24	40	5	15	84	14.4
Denning Point	35.6	2	..	1	20	15	..	38	6.5
Wappinger Creek	42.0	..	..	5	2	4	..	11	1.9
"B" Buoy	48.0	..	4	1	16	8	..	29	5.0
Crum Elbow	53.6	..	8	3	21	13	..	45	7.7
Indian Kill	57.6	..	6	2	30	7	3	48	8.2
Esopus Light	59.1	*	1	..	7	15	9	32	5.5
Rondout Creek	62.0	1	..	9	1	1	1	13	2.2
Cruger Island	69.1	..	..	..	3	1	2	6	1.0
Alsen	76.3	..	..	3	..	..	1	4	0.7
Athens	84.0	*	..	*	*	..	..	..	..
Four Mile Point	87.1	..	*	..	..	*	*	..	..
Coxsackie	90.2	*	..	..	..	1	..	1	0.2
Total by cruise		3	24	66	246	187	57	583	xxx
Per cent of total		0.5	4.1	11.3	42.2	32.1	9.8	xxx	100.0

* No sample taken.

nets caught the most striped bass eggs, the bottom trawl gave the best return per effort in the collection of larval and early post-larval striped bass. A summary of the relative efficiency of the three types of collecting apparatus used appears in Table 5.

TABLE 5. RELATIVE EFFICIENCY OF NETS USED DURING SPAWNING GROUND SURVEY IN THE HUDSON RIVER IN 1955

	Surface plankton net			Sub-surface plankton net			Bottom trawl			All gear		
Cruise	Effort in hours	Eggs per hour	Larvae and early post-larvae per hour	Effort in hours	Eggs per hour	Larvae and early post-larvae per hour	Effort in hours	Eggs per hour	Larvae and early post-larvae per hour	Effort in hours	Eggs per hour	Larvae and early post-larvae per hour
I	7.5	1.33	0.13	6.2	4.68	0.32	1.0	0.00	0.00	14.7	2.65	0.20
II	7.9	0.89	0.25	6.7	2.24	3.28	1.6	0.00	0.00	16.2	1.36	1.48
III	6.8	0.00	0.44	6.3	0.48	6.19	1.2	0.00	20.00	14.3	0.21	4.62
IV	7.4	0.00	0.27	6.0	0.00	22.50	2.4	0.00	45.42	15.8	0.00	15.57
V	5.2	0.00	0.00	4.6	0.00	35.43	3.0	2.33	8.00	12.8	0.55	14.60
VI	4.3	0.00	0.00	3.3	0.00	2.73	2.3	0.00	20.87	9.9	0.00	5.76
Total.....	39.1	xxx	xxx	33.2	xxx	xxx	11.4	xxx	xxx	83.6	xxx	xxx
Mean.....	xxx	0.44	0.21	xxx	1.42	11.15	xxx	0.61	17.98	xxx	0.85	7.00

Young Striped Bass

In 1954 and 1955 shore seining for young striped bass was conducted from late spring through early fall. Young first appeared in shore collections during the last week of June in both years.

Young striped bass were most abundant in collections made in the brackish water section of the river. During the quantitative sampling carried out in 1955, a total of 214, or 77.5 per cent of those taken, were collected from the three stations below Poughkeepsie (Little Stony Point, Haverstraw, and Harmon). The aggregate number of young taken from three stations upriver from Poughkeepsie (Mills State Park, Alsen, and Coxsackie) was only 62, or 22.5 per cent of the total. Table 6 shows the results of the quantitative seining.

In 1954, the first year of the study, the downstream locations also yielded more young striped bass than did the upstream seining sites. Since no attempt at quantitative sampling was made during that year, a reliable comparison with the 1955 results cannot be made.

As noted, the abundance of young striped bass in the section of the river downstream from Poughkeepsie has been observed to be greater than in areas upstream from Poughkeepsie. Growth data compiled for the upstream and downstream locations in 1954 and 1955 showed that the young from downstream areas had increased in length significantly more by early September than had those from stations in the upper river (Figure 3).

A possible factor in the variability of the return per effort between upstream and downstream locations is turbidity. Marked fluctuations in the turbidity of the river exist in the area influenced by brackish water. These fluctuations are caused by a variety of occurrences, including the amount of runoff from the drainage area, weather conditions, and turnover resulting from the intrusion of salt water. The possibility exists that the consistently greater transparency of the water at upriver locations might allow young striped bass to escape capture by seine more readily than would be the case in the less transparent water encountered more regularly downstream. On several occasions at Coxsackie, seine samples were taken during daylight and at night within 12 hours of one another. No apparent difference was noted in comparing the numbers or size of daytime samples against those of collections made under the cover of darkness. It has been assumed on the basis of these trials that the variable transparency resulting from turbidity was probably a negligible factor in accounting for the

TABLE 6. NUMBERS OF YOUNG STRIPED BASS COLLECTED FROM SAMPLING STATIONS ON THE HUDSON RIVER IN 1955

Station	Miles above Yonkers	Numbers collected								Total by station	Per cent of total	Cumulative per cent
		June 23-24	July 7-8	July 20-22	August 3-4	August 17-18	August 31	September 14-15	September 28-29			
Harmon	12.5	..	3	7	8	10	5	9	11	53	19.2	19.2
Haverstraw	14.0	..	80	15	3	8	11	5	1	123	44.6	63.8
Little Stony Point	30.5	..	9	10	1	6	6	5	1	38	13.8	77.6
Mills State Park	60.0	3	1	..	16	6	..	1	3	30	10.9	88.5
Alsen	76.3	..	2	3	2	7	6	4	1	25	9.0	97.5
Coxsackie	90.2	..	..	..	1	3	..	3	..	7	2.5	100.0
Total		3	95	35	31	40	28	27	17	276	100.0	xxx

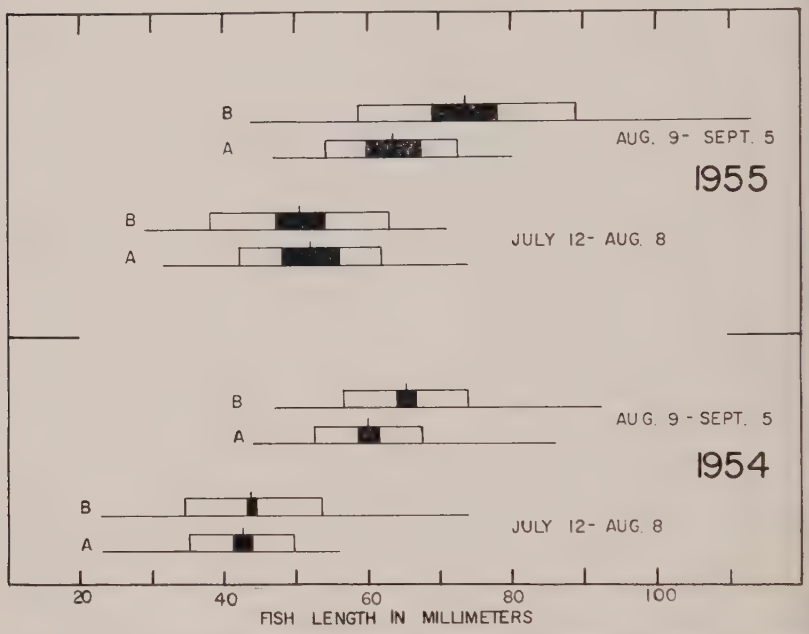

Figure 3. Graphic comparison of the variation in length between upriver (A) and downriver (B) collections of juvenile striped bass. In each case, the horizontal line indicates the range; the vertical line, the mean. The hollow rectangle is equal to 1 standard deviation on each side of the mean. The solid rectangle represents twice the standard error on each side.

contrast in the abundance of young between downriver and upriver locations.

Growth data for 1954 and 1955 collections of young striped bass are given in Tables 7 and 8. Measurements were made on the fork length of these fish and grouped by 3-millimeter intervals.

DISCUSSION AND CONCLUSIONS

Collections made during 1955 revealed the spawning area of the striped bass to include a section of the Hudson River from Bear Mountain upstream to a point near Kingston. On the basis of these collections, the principal spawning area was found to be centered in the vicinity of the United States Military Academy at West Point. Figure 4 shows the abundance of eggs as compared with the occurrence of larvae and early post-larvae of the striped bass for various sections of the river. On the basis of this graph, it can be seen that a large

TABLE 7. LENGTH-FREQUENCY OF YOUNG STRIPED BASS COLLECTED IN THE HUDSON RIVER DURING 1954

Cell mid-point in millimeters	Date and section of river*								
	June 28-July 11	July 12-August 8		August 9-September 5		September 6-October 3		October 4-November 4	
	B	B	A	B	A	B	A	B	A
17	2	..	..	..	..	..	..	..	..
20	11	..	..	..	..	..	..	..	..
23	24	4	2	..	..	..	..	..	..
26	44	13	1	..	..	..	..	..	..
29	28	22	5	..	..	..	..	..	..
32	7	43	11	..	..	..	..	..	..
35	8	61	7	..	..	..	..	..	..
38	10	72	7	..	..	..	..	..	..
41	1	56	16	..	..	..	..	..	..
44	3	76	26	..	3	..	..	..	..
47	..	69	16	3	3	..	..	..	..
50	..	57	18	6	9	1	..	1	..
53	..	38	5	4	9	..	..	..	..
56	..	34	3	14	17	5	..	..	..
59	..	30	..	26	24	8	3	5	2
62	..	11	..	32	17	5	2	2	1
65	..	7	..	22	10	19	3	6	1
68	..	4	..	20	8	13	4	6	3
71	..	2	..	16	4	23	1	5	1
74	..	1	..	13	4	30	1	5	..
77	..	..	..	5	2	23	..	7	2
80	..	..	..	7	..	22	1	12	..
83	..	..	..	3	..	21	2	14	2
86	..	..	..	4	1	13	..	16	..
89	..	..	..	1	..	8	..	26	..
92	..	..	..	1	..	7	..	26	..
95	..	..	..	..	..	4	..	6	..
98	..	..	..	..	..	4	..	5	..
101	..	..	..	..	..	6	..	2	1
104	..	..	..	..	..	2	..	1	2
107	..	..	..	..	..	..	..	..	..
110	..	..	..	..	..	..	..	1	..
Total.....	138	600	117	177	111	216	17	146	15
Mean.....	27.7	43.9	42.4	65.3	59.8	76.0	68.2	83.6	76.6

* Section of river denoted as follows: "B", below Poughkeepsie; "A", above Poughkeepsie.

percentage of the total spawning occurred within a relatively short segment of the river. This location is characterized by strong current, deep water, and rocky banks. Surface salinity here was in all cases

Table 8. Length-Frequency of Young Striped Bass Collected in the Hudson River During 1955

Cell mid-point in millimeters	Date and section of river*								
	June 24-July 11		July 12-August 8		August 9-September 5		September 6-October 3		October 12
	B	A	B	A	B	A	B	A	B
11	..	1	..	..	..	..	..	..	..
14	..	1	..	..	..	..	..	..	..
17	..	1	..	..	..	..	..	..	..
20	1	..	..	..	..	..	..	..	..
23	4	1	..	..	..	..	..	..	..
26	11	..	..	..	..	..	..	..	..
29	21	2	1	..	..	..	..	..	..
32	29	..	1	1	..	..	..	..	..
35	19	..	8	1	..	..	..	..	..
38	7	..	2	..	..	..	..	..	..
41	..	..	5	2	..	..	..	..	..
44	..	..	3	1	1	..	..	..	..
47	..	..	4	1	..	1	..	..	..
50	..	..	3	5	1	1	..	..	2
53	..	..	7	4	2	1	1	..	2
56	..	..	4	2	1	4	..	..	2
59	..	..	6	1	1	6	2	2	3
62	..	..	2	1	6	1	2	2	3
65	..	..	6	2	4	2	3	2	9
68	..	..	3	..	7	4	..	1	8
71	..	..	1	..	2	..	1	..	4
74	..	..	..	1	4	1	1	..	9
77	..	..	..	..	2	1	..	1	12
80	..	..	..	..	3	3	5	..	10
83	..	..	..	..	..	..	1	..	7
86	..	..	..	..	2	..	3	..	10
89	..	..	..	..	4	..	3	1	6
92	..	..	..	..	1	..	2	1	2
95	..	..	..	..	1	..	2	..	..
98	..	..	..	..	1	..	2	..	2
101	..	..	..	..	..	..	1	..	2
104	..	..	..	..	2	..	..	..	..
107	..	..	..	..	..	..	2	..	..
110	..	..	..	..	..	..	..	..	2
113	..	..	..	..	1	..	..	..	..
116	..	..	..	..	..	..	..	1	..
119	..	..	..	..	..	..	..	..	..
122	..	..	..	..	..	..	..	1	..
Total.....	92	6	56	22	46	25	31	12	95
Mean.....	31.5	20.5	50.5	51.8	73.7	63.3	84.8	78.0	76.4

* Section of river denoted as follows: "B", below Poughkeepsie; "A", above Poughkeepsie.

1 part per thousand or less. By contrast, the river immediately below Bear Mountain (farthest point downstream from which striped bass

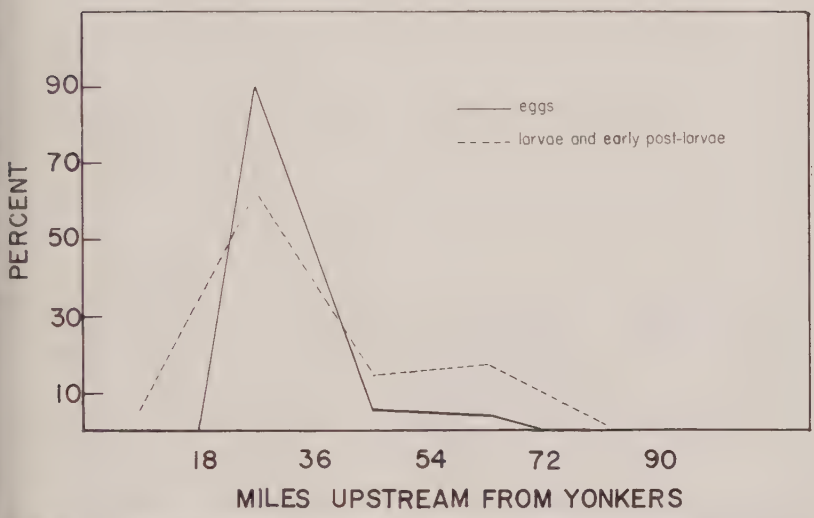

Figure 4. Distribution of the eggs and of the larvae and early post-larvae collected in 1955.

eggs were taken) becomes much wider and is subjected to higher salinity.

The findings concerning the relationship of brackish water to striped bass spawning are in close agreement with those of studies made in Virginia as reported by Tresselt (1952) and Massmann *et al.* (1952) for rivers tributary to Chesapeake Bay. They reported that the most intense striped bass spawning occurred within a short distance (about 25 miles) above the beginning of essentially fresh water.

The distribution of larval and early post-larval striped bass closely coincided with the locations from which striped bass eggs were collected. Although the plankton sampling program carried out was not designed to give quantitative data, the effort was relatively equal throughout the course of collections, and a reasonably accurate comparison of results may be made. A point of particular interest may be observed in Table 5. During the early cruises the larvae were taken only in the surface and subsurface (or mid-water) plankton nets. In the course of the later cruises, larvae and early post-larvae were taken regularly and in good numbers with the bottom trawl as well as with the subsurface net. However, few or none were present in collections made with the surface plankton nets. It appears that the general tendency is for a dispersal toward the bottom as feeding begins. In the process of sorting larval fish, it was noted that striped bass of

approximately 8 millimeters had been feeding on relatively large crustaceans.

Striped bass spawning had commenced by May 17 and continued until at least June 16. It is believed that little significant spawning had occurred prior to Cruise I which began on May 16. It may be seen from Figure 5 that only small numbers of larvae were recovered during the period when most of the eggs were collected. Over 80 per cent of the eggs taken during this study were from collections made between May 17 and May 27. These findings corroborate the views of Greeley concerning the time during which striped bass spawn in the Hudson River.

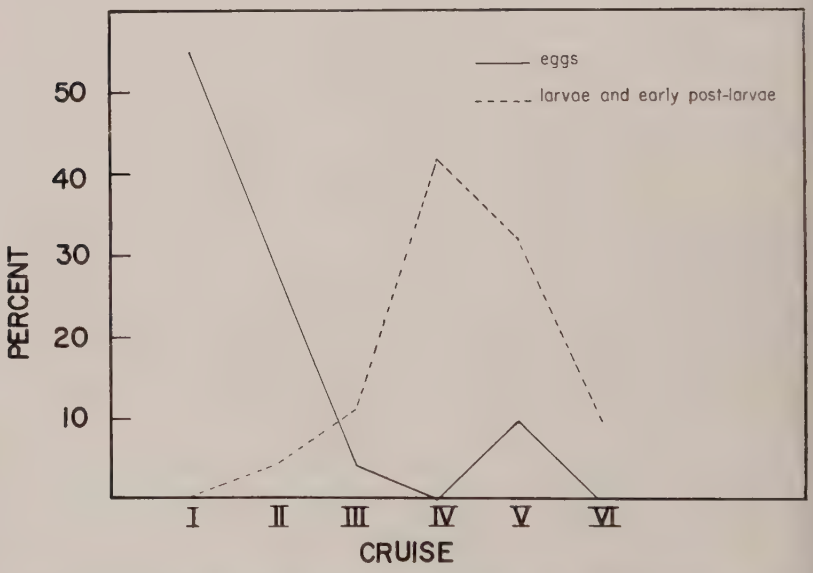

Figure 5. Percentage of eggs and of larvae and early post-larvae by cruise. (See text for duration of each cruise)

Young-of-the-year striped bass were observed to be most abundant in the downstream "brackish" area of the river. A comparison of the growth rates for young striped bass collected above and below Poughkeepsie demonstrated that those in the lower river had, by early September, increased significantly more in length than had the young captured upstream from Poughkeepsie. This is demonstrated in Figure 3.

On the basis of these observations, the most desirable nursery area for young striped bass in the Hudson River appears to be located in the section generally considered to be brackish. A partial explanation of this may lie in the increased productivity of food organisms, such as *Gammarus* and other small Crustacea, in these downstream waters. Coupled with this, some consideration should be given to the possible effects of the river flow, together with tidal current, which in the aggregate provided for more dispersal of larvae to downstream areas.

Figure 6. Hudson River at Harmon. Young striped bass were abundant at this location.

In general, young striped bass were most abundant at locations with a pronounced current and with a sand or gravel bottom. Figure 6 shows a typical seining site. In some cases, however, they were taken in numbers from sheltered coves with a sticky or soft bottom. It may be concluded that the young are not restricted to specific habitat conditions.

Data from repeated seining at selected stations employed in quantitative sampling of young striped bass gives considerable promise to the possibility that year-class strength may be gauged effectively by these methods. The results per unit of effort (which may be seen in Table 6) remained quite constant from the middle of July through late September. This method would probably not prove very effective

Figure 7. Young-of-the-year striped bass taken at Croton Point on October 12, 1955. Fork length of upper fish was 94 millimeters; that of lower fish, 55 millimeters.

after October 1, at which time the young will have grown to a size (Figure 7) which would make them capable of escaping the small seine utilized in collecting.

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TOE CLIPPING VARYING HARES FOR TRACK IDENTIFICATION[1]

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ABSTRACT

In the course of studies to determine the possibilities of re-establishing varying hares in certain sections of the State, a toe-clipping method was devised for marking hares for track recognition. Although conditions of the study did not allow a thorough investigation of the utility of the method, it proved a valuable aid and the experience gained indicated it affords a means for making detailed life history studies of varying hare populations.

The method involves the surgical removal of no more than one toe-end on each hind foot to produce readily identifiable notched footprints in snow. Up to 24 hares can be so marked without duplication. The track of each can be identified and followed for determinations of daily cruising radius, home range, and other data relating to life history and population dynamics of the species. By thus introducing a known quantity into a population, track surveys might be used to determine abundance levels. Availability of suitable snow conditions and the relatively small proven number of hares that can be marked without duplication are its major recognized limitations.

The ability to distinguish between individuals or groups of a wildlife species is of great importance in collecting life history and population dynamics data. A great number of methods have been described. Numbered bands or tags, color applied either directly to plumage or pelage (Wadkins, 1948), colored or design materials fastened securely to the individual (Edminster, 1938; Taber, 1949), and clipped feathers (Edminster, 1938), fur (Baumgartner, 1940), or distal extremities (Blair, 1940) have been used to make possible subsequent recognition of specific individuals in order to determine behavior patterns, abundance levels, and other data necessary to establish bases for management.

Most marking techniques require that recovery or clear sight contacts be made in order to assure identification. Trippensee (1934) applied a dye paste on the feet of three cottontail rabbits as a means of identifying stained tracks on snow. No indication was given of the durability of this marking technique other than a brief account of tracking one rabbit to a burrow from which it emerged 28 hours later.

This paper describes a toe-clipping method of marking varying hares. It was developed during field studies aimed at determining the possibilities for re-establishing hares by restocking in potentially

[1] A contribution of Federal Aid in Fish and Wildlife Restoration Projects W-22-R and W-84-R.

suitable habitats from which the species had been extirpated and where natural restocking from occupied range was improbable because of distance or lack of connecting avenues of suitable cover. A few liberations also were made in areas already supporting native hares, as a control. Hares for liberation were obtained first from game farm stock and later from stock trapped in native hare range. In addition to toe clipping, all hares liberated were ear-tagged.

Because this technique was incidental to the major purpose of the study and was not developed until the later stages, its potentialities could not be fully explored. However, since it appears to offer excellent opportunities for detailed studies of varying hare populations, it is described here in the hope that others will have occasion to test its validity on a wider scope.

TOE CLIPPING

Toe clipping is best accomplished by two persons, one to hold the hare and the other to remove the toe-end (Figure 1).[2] The hare

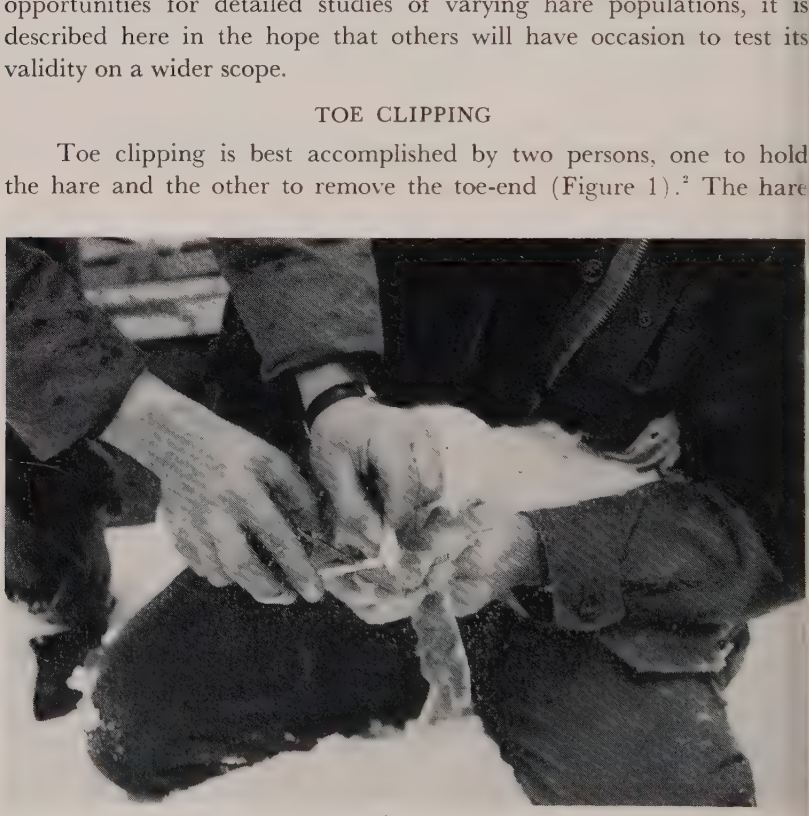

Figure 1. Toe clipping a varying hare.

[2] In handling varying hares care should be exercised to keep clear of their mouths. While definitely not of a vicious nature, often they will bite tenaciously any objects held close to their mouth and are capable of inflicting a deep and painful wound.

is held by one hand at the narrowest point on the hind legs, just above the feet. The forefinger of the holding hand should be placed between the legs to assure a good grip and at the same time serve as a spacer to prevent broken leg bones in the hare's struggles to escape. The hare's foreparts are held and cradled between the body and arm.[3] The other hand is used to separate the feet, at the same time isolating the toe to be amputated and drawing back all the loose skin. After amputation this excess skin helps cover and form a pad over the wound.

The operator positions the lower blade of heavy, sharp scissors beneath the joint separating the metatarsal and phalange bones. The toe is held flexed over the blade to help find the joint and the cut is made.

There appears to be very little pain and only a slight oozing of blood is involved in the operation. No evidence of infection was noted in any wounds made by toe clipping, even during the summer months and in rough wire-bottom pens where wounds were re-opened frequently. It was characteristic of the hares to keep the wounds licked clean as soon as the fright induced by handling had subsided.

Utilizing all possible combinations, and taking no more than one toe-end from each hind foot, 24 hares can be marked without duplication. Of this number, eight would have only one foot affected while 16 would have a toe-end on each foot removed. For ease in recording toe-end removal and track identification data, toes were numbered from the inner one outward. The letters "R" and "L" were used to designate the right and left foot, respectively. Thus, the inner toe on the right foot was recorded as 1R; the outer toe on the left foot as 4L. Where both toes concerned were from the same hare they were recorded as 1R-4L.

TRACK RECOGNITION

Some of the data gathered relating to the use of toe clipping to allow recognition of individuals are described below.

A group of 10 toe-clipped hares was released January 18, 1947. In a survey the following day tracks of individuals were easily identified and distinguished from one another and from those made by native hares. Further track identification surveys were impossible until 19 days after the release date, partly because of unusually unfavorable

[3] Use of a muslin sack (not shown in the illustration) to encase all but the hind feet usually eliminates further struggling. Presumably a holding device could be employed to allow a one-man operation.

tracking conditions. At that time two notched hare tracks were located and identified as 3L and 4L. Each hare was easily tracked for several hundred feet. Each was found dead and the earlier track identifications were verified. There was no sign of complications or infection because of the toe clipping. In subsequent surveys in the area, only unmarked tracks were found and it was concluded that all 10 liberated hares had died. (The stock used in this liberation attempt was game farm reared. Subsequent studies showed such stock to have an extremely low rate of survival even when released during summer months. Weather conditions immediately following release in this instance were unusually severe.)

Another group, including 27 toe-clipped and five unclipped hares, was released February 3, 1956. A portion of the potentially inhabited area surrounding the release point was surveyed for survival data on each of two days. The identities and locations for 11 survivors were established 3 days after release. A track with no toes missing also was identified. In another survey 17 days after release, 14 survivors were identified and their locations in relation to the release point were plotted. Tracks showing all toes intact indicated survival of an additional two unclipped hares.

Although in the latter survey many of the tracks had drifted over and others were partially obliterated, identification was usually established in from 1 to 30 feet from the time each track was encountered. From one to three hares had used some trails, often involving travel in both directions. Although tracks usually could not be identified in the main avenues of travel, identities were easily established at points where individuals branched off.

All of the 107 transferred wild hares released in 1948 and 1949 were used to test an alternate method of toe clipping which employed a heavy thread tourniquet to create a tight stricture around the toe. Small-scale pen experiments had indicated this to be an effective method of causing the toe-end beyond the tie point to mortify and slough off in from 2 to 5 weeks. For a time it appeared to have advantages over the surgical toe clipping. It later proved unreliable when some hares so treated were recovered with all toes intact.

This variation of the toe-clipping method is mentioned only because many of the available track identification and some of the recovery records were obtained from hares so treated. In all they provided 26 records of survival. This total was influenced by the fact that some hares had moved as much as 2 miles from original release points

and were not located until a year or two after release. In two cases tracks indicating the same missing toes were recorded from nearby localities and may have been duplicates. Although exact identities may have been confused where tourniquets had been applied to two toes and only one was effective in causing loss of a toe-end, a notched track was considered conclusive evidence of a liberated hare.

Box trapping was attempted on a limited scale in areas supporting survivors "marked" by use of tourniquets, and their progeny. In all, five hares were recaptured. As snow conditions would permit, track "readings" were made before a hare's toe condition was examined. With one exception no difficulty was experienced in determining accurately from the tracks whether or not toes were missing, and, if missing, which ones. In the exception, capture was made late during a 4-inch fall of very dry, fluffy snow. In addition to the snow which had tumbled in from the margins of the tracks, some snow had fallen and partially obscured toe marks after the tracks had been made. The absence of a specific toe-end was not clearly indicated although the print of the left foot was noticeably narrower than that of the right. In a few tracks the narrowed print gave the impression that 1L was missing. Examination of the hare disclosed that 3L had been removed.

Recaptured hare having toe 1L clipped

A tourniquet had been applied when the hare was a 400-gram juvenile. During a tracking survey of the same area the following day, after an overnight light rain had compacted the snow and improved tracking conditions, 3L tracks were found in the vicinity. A survey of the same area the following winter also disclosed a 3L track. No further recoveries of the hare were made to permit a direct comparison with its tracks.

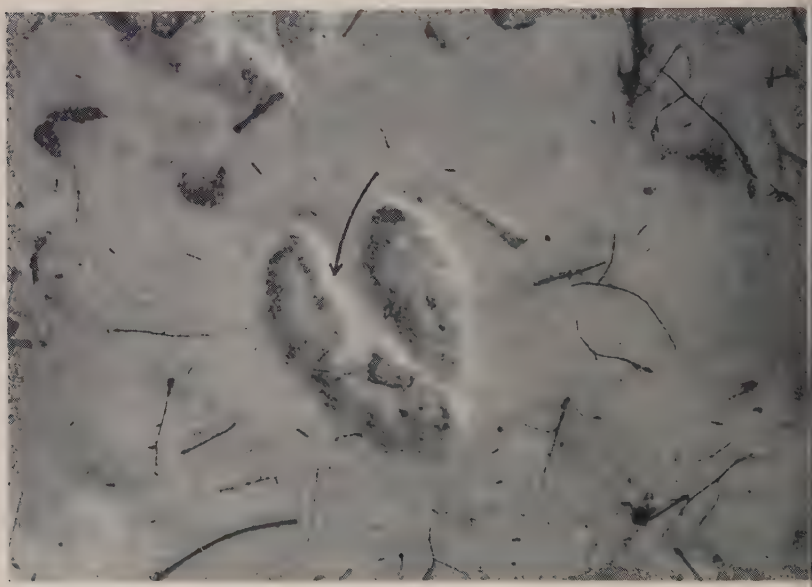

Figure 2. Varying hare track with toe-end 1L missing (arrow). This track was made under the shelter of a coniferous tree on a powder snow dampened by a drizzle of rain.

The notched tracks made by toe-clipped hares (Figures 2 and 3) were clearly recognizable in most types of snow. A wet packing snow, a granular snow, or a very light fall of dry snow on a heavy crust afforded the clearest prints. Fluffy dry snow more than ¾ inch deep was least apt to afford a clear print.

APPLICATION OF THE METHOD

In the study mentioned, the potential for making the most efficient use of track recognition could not be realized because of limited job objectives and shortcomings in the tourniquet technique. However, it was established that varying hares can be quickly and

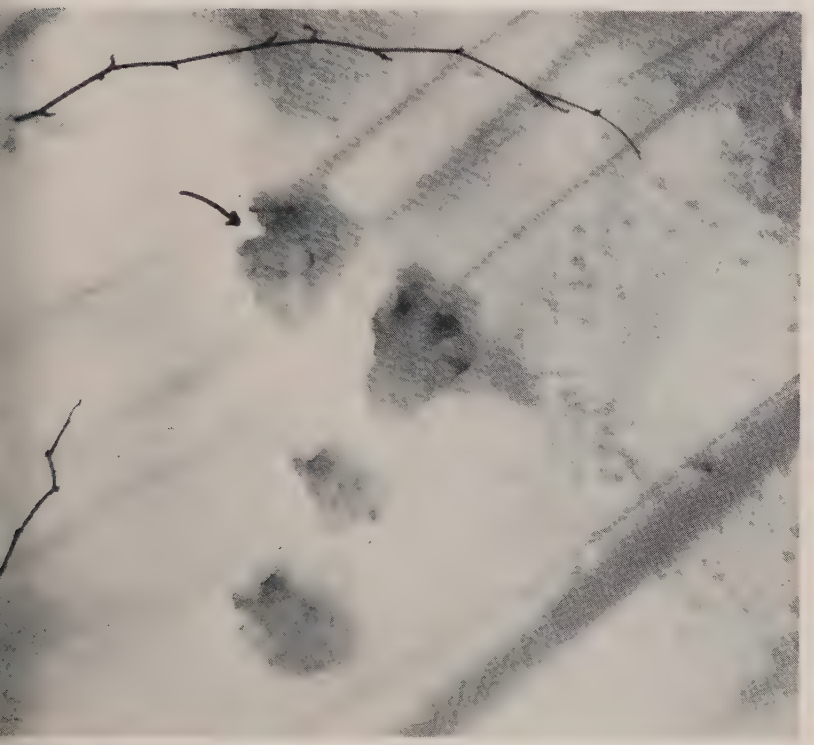

Figure 3. Varying hare track in a wet, packing snow showing toe-end 4L missing (arrow). Such snow conditions might make use of toes on the front feet feasible.

permanently marked with no apparent complications or effect on the welfare of the animals, and that thereafter the existence and identification of individual hares in a population can be determined readily from footprints in the snow.

In addition to the way in which toe clipping has been used the method appears to offer a means for making detailed studies of varying hare populations. The ability to identify individuals by their tracks would make it possible to keep in contact with recognized individuals within a hare population during the winter months throughout their life span after only one handling. Winter cruising radius and home range could be plotted in detail for each survivor. Presumably, the typically confusing maze of tracks characteristic of good hare range could be converted into numbers of inhabitants of that range by using as an index the number of marked tracks and the number of hares

they represent as compared with the total count of tracks along a census route. The continued existence of known individuals in a winter population could be determined periodically for information pertaining to longevity, age composition, population levels, population shifts, and other aspects of life history and population dynamics. Unlike many survey methods which disrupt the normal routine of the animal at the time contact to gather information is made, most activities recorded from track observations would reflect normal hare responses to normally-encountered stimuli.

A few limitations in the use of the method are readily apparent. It has only seasonal application and even then can be used effectively only as weather conditions will allow.

The number of hares which it has been demonstrated can be successfully marked without duplication is limited. No attempt was made to mark front feet for track identification. Presumably recognition of toe-clipped front feet would be possible on ideal tracking snows. However, it seems probable that recognition of the tracks of marked front feet on snows which recorded a less than perfect imprint would be more difficult than "reading" hind foot prints and would introduce increased possibilities for errors in identification.

It has been suggested, too, that in areas of very high hare densities a major portion of the tracks would be indistinguishable in the common runways used for most travels. Under such conditions observations and collection of data would be even more restricted by weather as it affected movements of the hares laterally away from major runways.

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SUCCESS OF NATURAL SPAWNING OF RAINBOW TROUT IN THE FINGER LAKES REGION OF NEW YORK[1]

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ABSTRACT

The efficiency of natural spawning in three Finger Lakes tributaries supporting natural spawning runs was measured by redd sampling. Forty-five redds were excavated when eggs were at the eyed stage. The mean pre-eyed loss was 11 per cent, the median 8 per cent. Only three redds had losses greater than 25 per cent. Nonfertilization accounted for 2 per cent of the losses. No correlation was found between pre-eyed losses and the amount of fine material (silt and clay) within the redd. The amount of fine material exceeded 1 per cent (by weight) in only one redd.

Maintenance of substantial rainbow trout populations in Skaneateles, Seneca, Keuka, and Canandaigua Lakes has been due largely to natural reproduction following introduction of this species in 1880 (Rayner, 1941). Supplementary stocking has been done, especially in years of unusually hot or dry weather that threatened survival of young fish. Owasco Lake formerly produced good rainbow trout fishing, but the population has been at a low ebb for over a decade. Cayuga Lake has never supported a large population of rainbow trout.

Natural history, population dynamics, and management of the rainbow trout in the Finger Lakes are currently under joint investigation by the New York Conservation Department and Cornell University. This study constituted a phase of the investigation devoted to the survival of naturally-spawned ova.

The efficiency of natural reproduction by salmonids is now considered to be quite high, at least until the fry emerge from the gravel. Hobbs (1937, 1940, 1948), working in New Zealand, indicated that losses greater than 10 per cent in the egg stage are to be considered unusual. Where heavy loss occurred, it was much greater in the pre-

[1] Derived from a Master's thesis submitted to the Graduate School, Cornell University. The author is grateful to Dr. Dwight A. Webster, Associate Professor of Fishery Biology, Cornell University, who gave the initial impetus to this study, and advice on design and preparation of the manuscript. Mr. Benno P. Warkentin, Assistant in Agronomy, described the technique used for particle size analysis. The equipment used in this phase of the study was lent by the Soils Testing Laboratory of the Department of Agronomy. Dr. Douglas D. Robson, Assistant Professor of Biological Statistics, aided in the data analysis. Photographs were taken by Mr. Douglass M. Payne, Laboratory Technician, Department of Conservation. Cooperation of landowners, especially those along Grout Brook, was appreciated. Mr. Paul C. Neth and especially Mr. Wilbur L. Hartman, Research Assistants in the Department of Conservation, aided in the field work.

eyed stage than in later development. He also concluded that heav losses are the outcome of adverse environmental conditions and thei extent depends primarily on the amount of very fine material in th redds during the pre-eyed stage. Briggs (1953) cited losses of 14 to 3 per cent in Prairie Creek, California, and several others (Shapovalov 1937; Shapovalov and Berrian, 1940; Shaw and Maga, 1943) hav reported high losses of ova planted artificially in gravel beds. Man of these authors have referred to the harmful effects of silt upon th survival of ova in the gravel, yet little quantitative work has bee done to establish the extent of these effects.

A redd sampling program was conducted in 1955 on the inle of Skaneateles, Seneca, and Keuka Lakes to determine survival o naturally-spawned eggs to the eyed stage and the amount of fine ma terial deposited in the gravel of redds. The study was designed to allo comparison of survival: (1) in different streams; and (2) associate with various degrees of accumulation of fine material in the grave

Frequently used terms are defined below. Terms applied to th nest are those of Burner (1951), while particle size is denoted a cording to the Wentworth Classification (Welch, 1948).

Redd — entire area of gravel disturbed by female trout i nest building.

Egg pocket — part of redd in which eggs are actually deposite (one or more per redd).

Eyed egg — egg that has reached the stage of developme wherein the pigmented eye is visible.

Tailspill — loose pile of material formed on the downstrea end of the redd.

Silt — material between 0.062 and 0.004 millimeter size.

Clay — material smaller than 0.004 millimeter in siz

STUDY AREAS

Relevant topographic information on the streams under study summarized in Table 1. The general limits of the areas most utiliz in spawning are included. The summer temperatures indicated are t maxima recorded by State biologists and Cornell University gradua students in the past few years. The lower portions of these streams a unstable. Shifts in course and changes in stream character affecti the spawning area are common in these sections.

TABLE 1. RELEVANT TOPOGRAPHIC INFORMATION ON THE THREE FINGER LAKES TRIBUTARIES STUDIED *

Feature	Keuka Inlet	Catherine Creek	Grout Brook
Total length (miles)	5	17	6½
Elevation (feet)			
At source	1,100	1,650	1,700
At lake level	710	445	875
Gradient (feet per mile)	78	71	127
Watershed (square miles)	24	90§	10
Portion used in spawning			
Length (miles)	3	8	4
Upper limit			
Location	Softwater Creek	Pine Valley	Scott Cemetery
Elevation (feet)	950	900	1,300
Lower limit			
Location	Private airport	Diversion channel	Skaneateles Lake
Elevation (feet)	720	465	875
Gradient (feet per mile)	82	58	106
Summer temperature maximum	65°F.	85°F.	65°F.

* Derived from U. S. Geological Survey maps.
§ Excluding Glen Brook.

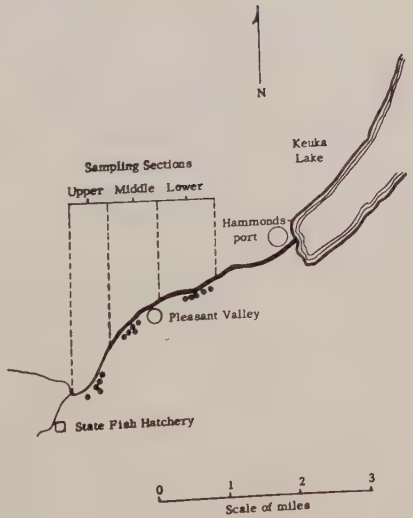
KEUKA INLET (COLD BROOK)

Keuka Inlet (Figure 1) flows in a northeasterly direction through Steuben County from Bath to Keuka Lake at Hammondsport. Its banks are mostly wooded above Pleasant Valley, with some vineyards adjoining the stream. Below Pleasant Valley wooded areas alternate with hay fields, wooded banks predominating. The stream is fed by many cool springs near its source and remains cool throughout the year. Summer temperatures seldom exceed 65° F. except in the lower flat region of the stream.[2]

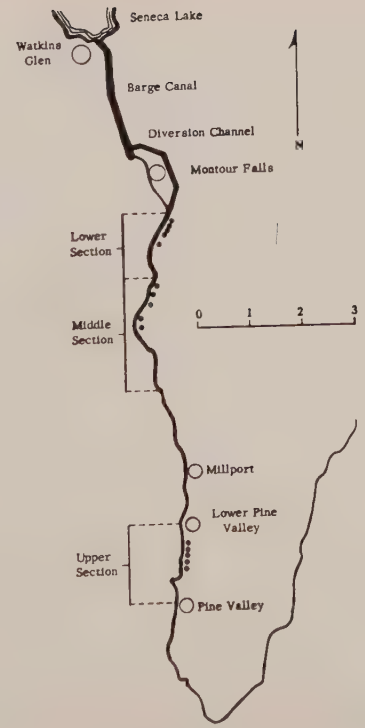
The normal salmonid population consists mainly of rainbow trout parr and occasional brown trout. The main run of spawning fish from Keuka Lake takes place in March. During 1955, a second run of trout occurred during the first week of May, and many new redds were constructed in the upper section of the stream.

Keuka Lake has not been stocked with rainbow trout during the

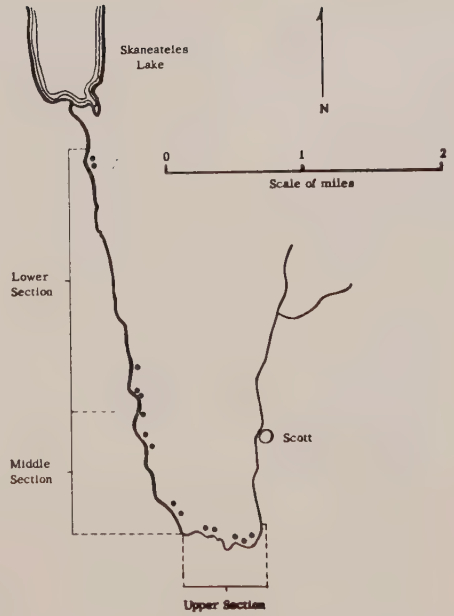
[2] W. L. Hartman, Cornell University, personal communication, 1956.



KEUKA INLET



CATHERINE CREEK



GROUT BROOK

Figure 1. Maps of the study streams showing sampling sections and locations of redds sampled (dots).

last six years. Tributaries in Steuben County received their last allotment of fingerling rainbow trout in 1951[3].

CATHERINE CREEK

Catherine Creek (Figure 1) follows a U-shaped course through wooded areas in Chemung County until it reaches Pine Valley. It then flows in a northerly direction through open farming country with wooded or brushy banks until it reaches the diversion channel built by the Army Engineers around Montour Falls (Schuyler County). The flow splits here into the old channel through Montour Falls and the flood control diversion channel. The flows rejoin and subsequently form the Barge Canal Terminal at Watkins Glen.

The lower 8 miles of the stream proper, from Pine Valley to the diversion channel, are subject to warming in the summer. Temperatures in the high seventies are frequently recorded[4] and occasional readings to 85° F. are known.[5] This does not provide a suitable environment for trout and they are not abundant here during the summer months. The principal spawning grounds for the rainbow trout of Seneca Lake are located in this area, however, and the study was thus concerned with this section. The spawning run occurs mainly in March. No evidence of a late run was noted in 1955.

Seneca Lake received token stockings in 1951 and 1952, but no rainbow trout have been stocked in the lake since that time. Tributary streams in Schuyler County have not been stocked since 1951, while those in Chemung County received from 1,100 to 1,700 yearlings per year from 1950 to 1953.[6]

GROUT BROOK

Grout Brook (Figure 1), the inlet of Skaneateles Lake, follows a U-shaped course through mostly wooded areas in Cortland County. It remains cool throughout the summer months due to an abundance of springs and shaded banks. Temperatures in excess of 65° F. are seldom recorded above its lower reaches.[7]

The trout population consists mainly of rainbow trout parr and occasional brown trout. Rayner (1941) placed the main run in early April in this stream. In 1942, there were two peaks, one during the

[3] R. M. Roecker, Western Fisheries District, personal communication, 1956.
[4] Hartman, *loc. cit.*
[5] U. B. Stone, Western Fisheries District, personal communication, 1956.
[6] Roecker, *loc. cit.*
[7] Hartman, *loc. cit.*

third week of March, the second in the first week of April.[8] The run is probably later than that of the other streams because Grout Brook remains icebound to a later date.

Skaneateles Lake and Grout Brook receive annual plantings of rainbow trout by the U. S. Fish and Wildlife Service and the Onondaga County Park and Regional Planning Board. The lake has received approximately 10,000 to 15,000 yearlings annually, while Grout Brook received 1,300 in 1953 and 1,500 in 1954.[9]

REDD SAMPLING

This study had three objectives: (1) to determine the survival rate of naturally-spawned eggs to the eyed stage; (2) to determine the amount of fine material deposited in the gravel of the redds; and (3) to determine if a relationship exists between egg survival and the accumulation of fine material. Each stream was divided into three sampling sections corresponding to the major concentrations of spawning activity. These sections are indicated on Figure 1 and are detailed in Table 2.

Frequent field trips were made in late March and early April, 1955, to locate redds under construction. A record of stream temperatures was kept to estimate the development of ova. Marking the redds was considered, but the idea was discarded because of heavy fishing pressure and the possibility of attracting attention to the areas under study. It was difficult to relocate a number of redds, and some kind of marking system would definitely be desirable if it were essential to relocate the same ones. This was especially true in Keuka Inlet, where reworking of the gravel by the second spawning run made relocation of many of the earlier redds impossible. Excavation of redds began on April 17 and was completed on June 9.

Sample redds were selected on the basis of accessibility and attainment of the eyed stage of development by the eggs. The procedure was as follows. On a date likely to yield eyed eggs in a certain section (according to the temperature unit theory), the redds which had been located previously were excavated. When a redd could not be relocated, others in the vicinity were then excavated until the number required for the section was complete. Gravel removed from redds with eggs in the pre-eyed stage was replaced immediately.

[8] K. B. Nichols, Superintendent of Fish Culture, personal communication, 1956.
[9] A. C. Petty, Central Fisheries District, personal communication, 1956.

TABLE 2. BOUNDARIES OF SECTIONS SELECTED FOR REDD SAMPLING IN THREE FINGER LAKES TRIBUTARIES

Stream and section	Lower limit	Upper limit	Length (feet)	Gradient (per cent)
Keuka Inlet				
Lower	Beginning of spawning area at airport	Dam at Pleasant Valley	4,000	1.5
Middle	Dam at Pleasant Valley	900 foot contour	5,500	2.2
Upper	900 foot contour	Softwater Creek	5,000	1.0
Catherine Creek				
Lower	Diversion channel	Public parking area at 500 foot contour	7,500	0.5
Middle	Public parking area at 500 foot contour	Sleeper Creek	12,500	1.0
Upper	Lower Pine Valley	Pine Valley	7,000	1.4
Grout Brook				
Lower	First bridge above lake	1100 foot contour	11,100	2.0
Middle	1100 foot contour	Bridge at 1200 foot contour	5,400	1.9
Upper	Bridge at 1200 foot	Scott Union Cemetery	4,800	2.1

EXCAVATION OF REDDS

A specially constructed shovel (Figure 2), patterned somewhat after one described by Hobbs,[10] was used to obtain egg and gravel samples concurrently from the egg pockets. The shovel is a modified nursery spade. The blade, 14 inches long, tapers from 5½ inches at the butt to 4¾ inches in width above the tip. A steel hood 12½ inches long and 5½ inches in diameter is welded onto the blade. This hood is completely closed at the butt end. Approximately 2 inches of the blade are exposed to facilitate digging.

In excavating a redd, digging was started about a foot below the upstream end of the tailspill. The shovel was inserted vertically and worked down 4 to 6 inches into the gravel. It was then tilted and worked upstream slantwise until full. Then it was lifted carefully to avoid losing the contents and emptied into a large galvanized pan.

[10] D. F. Hobbs, New Zealand Marine Department, personal communication, 1955.

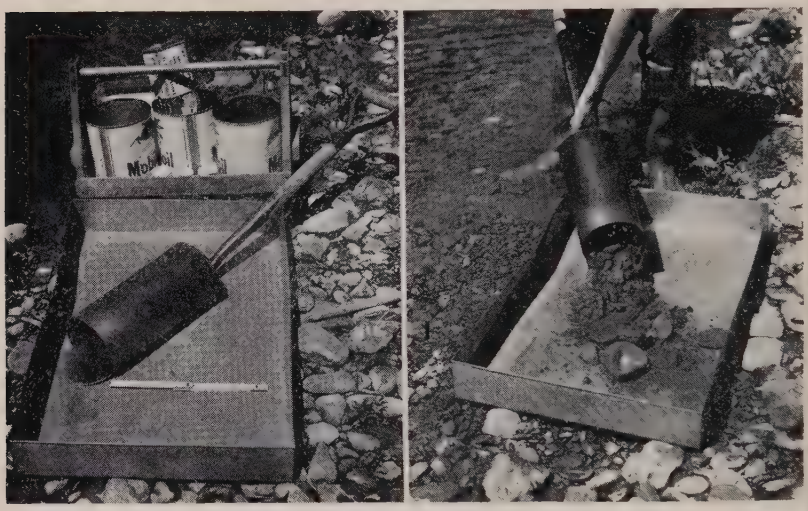


Figure 2. Equipment used in excavating a redd (left) and a typical gravel sample (right).

If no eggs were present, the sample was discarded and the process proceeded upstream until the egg pocket was penetrated.

When a single shovel full contained a number of eyed eggs, these were removed and the material in which they were contained was washed into a 5-quart oilcan where it was covered and retained for subsequent analysis. Excavation was continued until approximately 100 eggs were obtained. In some cases it was impossible to obtain that many eggs from a redd. Lack of eggs indicated that such a redd was probably the last spawning act of a nearly spent fish. Other redds were substituted for these, but toward the end of the season, suitable redds were difficult to locate.

Observations indicated that most of the fine material excavated from a redd remained within the hood of the shovel. Some material disturbed at the sides and tip of the shovel was carried downstream. When sampling was completed, the excavation was refilled to allow proper development of the remaining ova. No attempt was made to obtain all the eggs in any redd.

Eggs obtained in each sample were classified in the field. All living eyed eggs were picked out and placed in a bottle of 5 per cent acetic acid. The remaining eggs were divided into two groups, those obviously dead and those that were doubtful. Each of these groups was then placed in 5 per cent acetic acid.

In the laboratory, eggs classified as doubtful were re-examined with a binocular dissecting microscope and designated as either eyed or dead. All pre-eyed eggs were counted as losses. The use of the acetic acid solution aided in clearing some of the cloudy eggs for better viewing (Guyer, 1936). Samples were transferred to a solution of 5 per cent acetic acid and 10 per cent formalin for storage and later recheck.

All eggs within a redd do not reach the eyed stage at precisely the same time. There was no means for determining whether pre-eyed eggs in a redd approaching the eyed stage had died during the few days preceding excavation or had been killed during the excavation. Therefore, only redds containing well-eyed eggs were used in the analysis and all pre-eyed eggs were considered as losses.

Gravel Analysis

The gravel samples were dried with a water bath and weighed on a Torsion Balance with 0.05 gram accuracy. The entire sample was then screened through a sieve having 2-millimeter openings (0.079 inch). Material not passing the sieve was then weighed and the weight of material less than 2 millimeters in size was obtained by subtraction. This latter material was then divided by quartering until a sample of approximately 50 grams was obtained. This was oven-dried overnight at 105° C. A 10.00-gram subsample was then taken from this material and allowed to soak in 200 milliliters of distilled water for one to several days. Subsampling provided the only potential source of error in this technique. This error is probably not of great proportions and is not biased. All operations were carried out by a single person to minimize variation.

Following soaking, the subsample was transferred to a dispersion cup and thoroughly mixed with 10 milliliters of dispersing agent (Calgon, 44 grams per liter). The suspension was then washed into a 1-liter cylinder for sampling by the pipette technique (Kilmer and Alexander, 1949; Krumbein and Pettijohn, 1938). Two samples were removed from the cylinders at times dependent on temperature. These were evaporated, dried overnight at 110° C., and weighted on a chainomatic-type balance to 0.1 milligram accuracy. Corrections were made for the amount of dispersing agent present and calculations gave the total amounts of silt and clay found in the original sample. The proportion of sand present was then obtained by subtraction.

RESULTS

A total of 54 redds was excavated, 18 in each stream and 6 in each section. It was decided to limit the sample to 15 redds per stream, one redd being discarded from each section. Reasons for this included cases of obvious superimposition (pre-eyed eggs from the first and second spawnings being inseparable); redds sampled previously in the pre-eyed stage; and redds, when sampled, appearing to hold eyed eggs, but upon laboratory analysis found to be approaching the eyed stage. The data presented are thus based on 45 redds located as shown in Figure 1 in the areas delimited in Table 2.

A total of 4,433 eggs was examined, an average of 98.5 per redd. The actual range was from 37 to 162, with eleven samples based on fewer than 85 eggs (two samples on less than 50) and seven samples based on more than 115 eggs. Of the eggs examined, 496, or 11.2 per cent, were pre-eyed losses. Data on the 45 redds are presented in Table 3.

In a frequency distribution of pre-eyed losses (Figure 3), the median value was 8.0 per cent, while 25 per cent of the redds showed losses of less than 3.0 per cent, and 75 per cent less than 14.5 per cent. One redd in upper Keuka Inlet suffered 100 per cent loss, one in

TABLE 3. PRE-EYED LOSSES AND FINE MATERIAL CONTENT (IN PER CENT) FOUND IN SAMPLES OF RAINBOW TROUT REDDS IN THREE FINGER LAKES TRIBUTARIES

	Keuka Inlet		Catherine Creek		Grout Brook	
Section	Pre-eyed loss	Fine material*	Pre-eyed loss	Fine material*	Pre-eyed loss	Fine material*
Lower...	3.4	0.286	8.1	0.399	14.2	0.787
	22.9	0.579	18.6	0.150	2.7	1.103
	3.6	0.181	3.4	0.201	1.5	0.364
	14.2	0.012	0.9	0.108	0.8	0.381
	5.5	0.394	14.0	0.118	1.0	0.246
Middle..	10.0	0.222	45.2	0.287	13.3	0.411
	16.0	0.342	6.4	0.195	15.2	0.382
	10.0	0.219	6.5	0.297	0.9	0.160
	17.0	0.107	11.0	0.308	1.9	0.480
	86.2	0.078	6.8	0.094	11.7	0.344
Upper...	6.1	0.092	12.5	0.351	0.0	0.202
	11.8	0.353	7.4	0.407	8.1	0.306
	9.7	0.317	5.1	0.363	0.0	0.118
	100.0	0.488	7.0	0.403	0.9	0.245
	21.0	0.334	3.2	0.192	4.9	0.361

* Silt and clay.

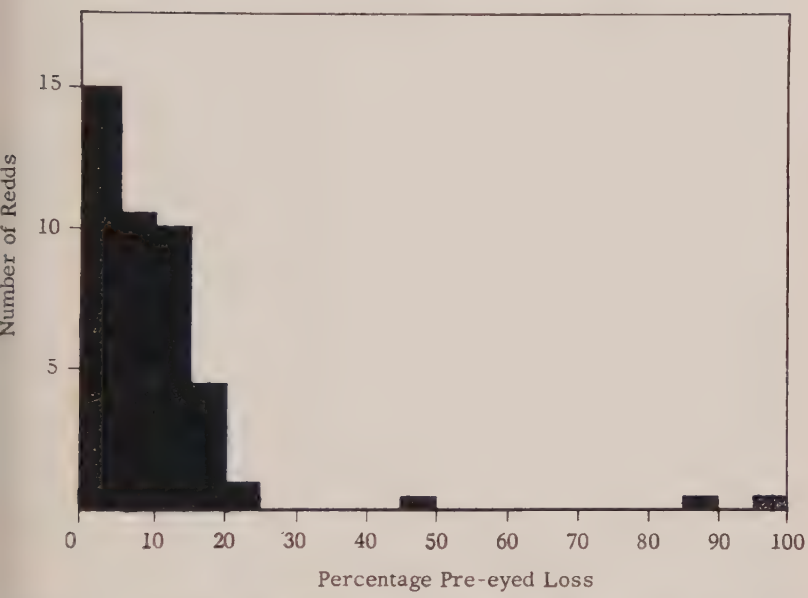


Figure 3. Frequency distribution of pre-eyed egg losses from rainbow trout redds in three Finger Lakes tributaries; class interval, 5 per cent.

middle Keuka Inlet 86 per cent, and one in middle Catherine Creek a loss of 45 per cent. No other losses exceeded 25 per cent. At the other end of the scale, two redds in Grout Brook showed no loss at all.

The nonfertilization loss amounted to 132 eggs, 2.3 per cent of the total. This figure is consistent with the findings of others (Hobbs, 1937; Cameron, 1940; Cramer, 1940; Rayner, 1941).

The gravel analysis indicated quantities not exceeding 20 per cent for sand, 1.0 per cent for silt, and 0.2 per cent for clay in the redd material.

DISCUSSION

There was a wide range in the degree of pre-eyed loss. Only three redds had losses greater than 25 per cent. Below this figure, however, there was great variation in the redds within a given section. Sectional variances were evaluated for each stream with Bartlett's test of homogeneity of variance (Bartlett, 1937) and found to be non-homogeneous. This indicates that the number of redds sampled within a section was too small to give a reliable estimate of the sectional mean. Certain procedures are available for estimating the number needed (Snedecor, 1946). Assuming the usual range in egg mortality

to be 0 to 25 per cent, 100 redd samples would be necessary to provide an estimate of the mean pre-eyed loss reliable to ± 2 per cent with 95 per cent confidence. It is felt, however, that 100 eggs per sample are sufficient for the estimation of losses within a redd. The work summarized by Hobbs (1948) for more than 700 samples is probably the most reliable estimate of mortality in the egg stage available.

Sampling redds for particle-size analysis presented another series of problems. It is very difficult to carry out work of this sort on a large scale, because the physical size of the samples required for the analysis becomes prohibitive. It is felt that the shovel used could be made somewhat smaller, thereby making the samples less cumbersome. However, the amount of fine material found in redds in good quality streams is very small, and the inclusion of one or two large rocks in a sample can change the percentage composition to such a degree that the significance of fine materials may be completely lost. Thus, in a small gravel sample, the inclusion of a single 3-inch stone may completely overshadow the total amount of fine material present. This problem increases as the physical size of the samples is decreased for ease in handling.

Mean egg survival for each stream could not be estimated by combining the data for its several sections because sampling was not weighted according to the concentration of spawning activity in each section. Means computed from these data would be biased against the areas of greatest spawning activity. Since the distribution of spawning activity varies from year to year, a study based on a proportional sampling program would be applicable to only a single year. An alternative procedure would be equal sampling in each section of a stream followed by weighting procedures based on the concentration of spawning activity in each year. It is felt that the latter procedure (with an adequate sample) would give greater flexibility to the application of the data. It will be noted that either proportional sampling or proportional weighting would require a knowledge of the actual amount of spawning that took place in the various sections of the stream.

Tests using chi-square, however, are valid for comparing pre-eyed losses between the streams by sections. The test is made on a section-by-section basis because an equal number of redds were sampled in each while spawning activity was not equally distributed throughout the stream. Using this method, Grout Brook (which appeared to have the lowest pre-eyed loss) was compared with Catherine

Creek (which appeared intermediate in loss). Catherine Creek was then compared with Keuka Inlet (which appeared to have the highest loss). In the first case, the test was biased against Grout Brook; in the second, against Catherine Creek. This follows because the specific comparisons were made on the basis of apparent stream rank. Thus the tabular values of chi-square represent a higher probability level than indicated. In other words, any chi-square value declared significant at the 5 per cent level of probability can actually be expected to occur, on the basis of chance, somewhat fewer than five times in one hundred.

The test for a given section is performed as follows:

	Stream X	Stream Y	Total
Number of live eggs	a	b	$a+b$
Number of dead eggs	c	d	$c+d$
Total	$a+c$	$b+d$	$a+b+c+d=n$

$$\text{Chi-square} = \frac{n\,(ad-bc)^2}{(a+b)\,(c+d)\,(a+c)\,(b+d)}$$

The results of these comparisons are shown in Table 4. Grout Brook had significantly fewer losses than Catherine Creek in all three sections. Catherine Creek had significantly fewer losses than Keuka Inlet in the upper and middle sections, while their lower sections were not significantly different.

TABLE 4. CHI-SQUARE VALUES FOR COMPARISONS OF PRE-EYED LOSSES IN CORRESPONDING SECTIONS OF THREE FINGER LAKES TRIBUTARIES

Comparison	Chi-square§
Grout Brook *vs.* Catherine Creek	
Lower section	5.21*
Middle section	7.36**
Upper section	12.41**
Catherine Creek *vs.* Keuka Inlet	
Lower section	0.03
Middle section	15.52**
Upper section	564.08**

§ Chi-square (1 degree freedom) = 3.84 (Probability 0.05), 6.64 (Probability 0.01).

* Significantly different at the 5 per cent level.

** Significantly different at the 1 per cent level.

The work of Hobbs (1937, 1940, 1948) is by far the most comprehensive study of the efficiency of natural reproduction among certain salmonids. His 1937 paper lists pre-eyed losses of 2.13 per cent for quinant salmon in one stream, and of 20.16 per cent and 4.04 per cent for brown trout in two other streams. His 1940 paper gives an over-all mean of 7.10 per cent pre-eyed loss in 235 eyed samples from brown trout and rainbow trout redds. His final paper (1948) gives a summary of collections from 711 redds containing 503,139 ova. The total loss before emergence was 7.6 per cent. Since his earlier works established the fact that the greatest part of the total loss takes place in the pre-eyed stage, we are probably justified in accepting a figure of about 7 per cent for pre-eyed losses in New Zealand. The median of 8 per cent recorded in the present study for the Finger Lakes region is of the same order.

Briggs (1953) has apparently done the only American work comparable to that of Hobbs, although he did not give separate mortality figures for the pre-eyed component. He found average mortalities as follows: silver salmon (22 samples), 25.7 per cent; king salmon (10 samples), 14.0 per cent; and steelhead trout (14 samples), 35.1 per cent. He also noted that high mortality was positively correlated with the presence of an oligochaete worm in the egg pits of a number of redds. By removing these samples from the totals, he arrived at the following average losses: silver salmon (18 samples), 14.8 per cent; and steelhead trout (7 samples), 13.7 per cent. While these values are higher than those of Hobbs, they may not be significantly different if we take into account the range of variation and the fact that the figures represent the total number dead at the time of sampling (sometimes after hatching). Briggs did not state the nature of the damage caused by the oligochaetes. No infestation with oligochaete worms or other parasites was noted in the Finger Lakes studies.

White (1930) reported hatches of 79 and 66 per cent from naturally-spawned brook trout eggs recovered from the gravel on the day after spawning. The first group was hatched in a hatchery trough, the second group in a wire container in the bed of the spawning stream.

Hazzard (1932) took samples from 21 brook trout redds near Ithaca, New York, at the eyed stage. He found that the percentage of eyed embryos ranged from 27 to 98.5 with a mean of 80 per cent.

There are several other reports of excavation of naturally-spawned eggs. Withler (1952) reported losses of 10 per cent prior to the eyed

tage for the sockeye salmon. Warner (1952) excavated redds of land-ocked salmon after fry emergence and noted that only 9 per cent of he dead eggs remaining were eyed. Losses of trout eggs in Yellowstone National Park were reported as 22 per cent after 4 days, and 34 per ent after 24 days in the gravel (Anonymous, 1953).

The mean loss during the pre-eyed stage for rainbow trout in the Finger Lakes streams studied lies between the values presented for New Zealand and those for California and probably within a range which can be accounted for by variation among individual redds.

Experiments on hatching steelhead trout eggs in artificial situa-ions were reported by Shapovalov (1937). Artificially-stripped eggs were placed in gravel in a glass aquarium and in a hatchery trough. These were compared with control lots hatched in the usual way. In one experiment, 30 per cent of the eggs in gravel produced emergent ry, but in the control lot 80 per cent of the eggs produced fry which ived until the test lot had completed emergence. The second experi-nent showed 80 per cent emergence from the gravel compared with 2 per cent for the control. Shapovalov stated that during the first xperiment heavy rains caused the hatchery water to become ". . . ex-remely and unusually muddy". This condition continued for 9 days. He considered that silt depositing in the gravel from this muddy water nay have been a factor causing the low survival in the first experiment.

The same author reported another similar experiment involving ilver salmon (Shapovalov and Berrian, 1940). Only 10 per cent of the ggs in the gravel produced fry compared with 48 per cent for the ontrol lot. The authors stated, "Some of the worst floods ever ex-erienced occurred while the eggs were in the gravel . . . and the vater in the hatchery troughs was laden with silt". It was the belief f the authors that most eggs were smothered ". . . by the large uantity of silt that had settled around them".

An experiment was described by Shaw and Maga (1943) in which rtificial gravel beds built in three hatchery troughs were planted with ilver salmon eggs. Two of the troughs were then subjected to the addi-ion of mining silt for 2 to 4 hours daily for 2 to 72 days. A control roup hatched in a basket in normal water produced a hatch of 80 er cent. Of the eggs placed in gravel 16 per cent of those not sub-ected to silting produced fry, compared with 1 per cent of those sub-ected to silting. The longer the exposure to silt, the lower was the ield. The authors concluded that the usual hatching methods were uperior to hatching in gravel beds and that, "Mine silt deposited on

gravel spawning beds during incubation results in negligible yields o fry". The silty materials applied to the nests raised the turbidity of th water at the head of the troughs to 1,300 p.p.m. suspended solids an an average of 83 p.p.m. was lost over each nest. There was, however no quantitative measure of the actual amount of silt deposited in th gravel at the end of the experiment.

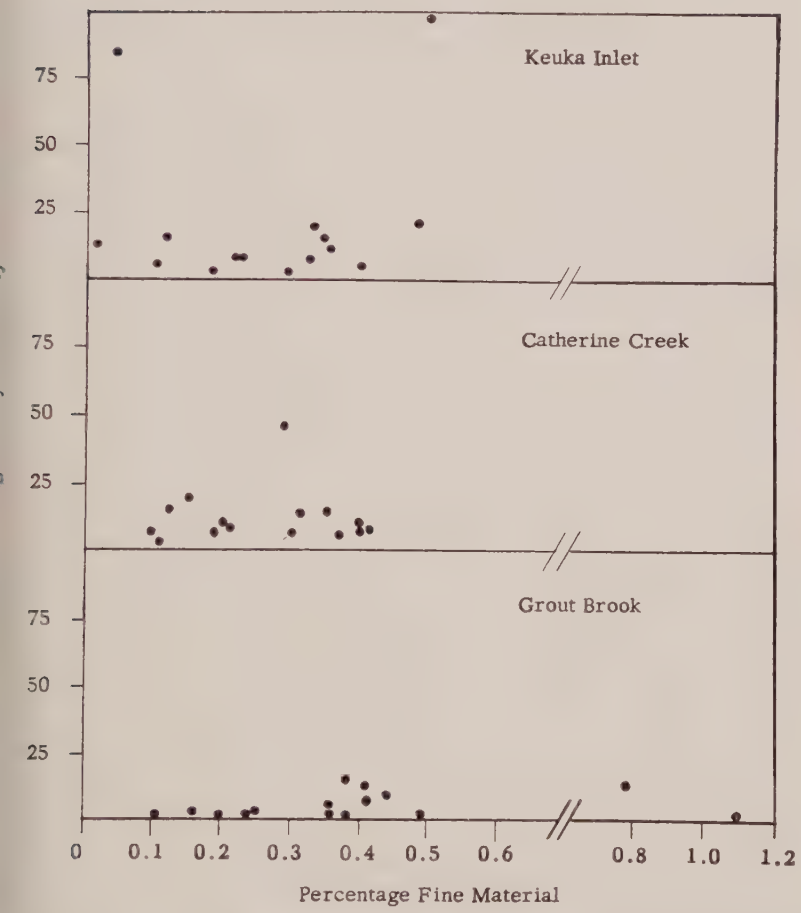
Burner (1951) estimated that Pacific salmon redds contained fro 3 to 11 per cent mud, silt, and sand. This estimate was based on visua observation of disturbed material.

Hobbs (1937) measured the composition of nine redds which hi observations had noted as "dirty". By the use of square-mesh sieve he screened the material down to 0.03 inch (0.76 millimeter). Whe the average of this fine material exceeded 4 per cent of the tota pre-eyed losses increased. In one stream (four redds) the loss wa 20.16 per cent, in another (one redd) it was 94.12 per cent. The othe streams tested showed less than 2.5 per cent fine material and pre eyed losses of less than 5 per cent. Hobbs included as fine materia part of that designated as sand in this paper, together with silt and clay

Within the ranges measured in the streams under study, depositio of sand, silt, and clay in the redds did not influence mortality. Sinc there was no apparent correlation with either silt or clay, thes were combined as "fine material" (Figure 4). Field observations ha led to the belief that some of the redds were dirty, but the actua determinations show that such qualitative observations may be mis leading (only one redd contained more than 1 per cent of fin material).

One redd in middle Keuka Inlet was considered muddy, althoug later measurement showed its fine material content one of the lowes in the stream. This redd suffered 86 per cent loss in the pre-eye stage. It was about 5 feet downstream from two redds which had bee sampled twice previously. Although walking on the tops of redds i not known to cause extensive mortality, the activity in this area ma have been a factor in the high pre-eyed loss.

A redd in upper Keuka Inlet which had 100 per cent mortalit also appeared unusually dirty. It turned out to have 0.5 per cent fin material in the contents. While this was a high value for this strea it was greatly exceeded in Grout Brook with less than 15 per cent los No explanation is offered as to the reason for the total loss of th redd. It was in a very exposed location on the inside of a stream ben Wickett (1954) presented evidence that the oxygen supply in wat



igure 4. Pre-eyed egg losses compared with percentage of fine material (silt plus clay) in redds in three Finger Lakes tributaries.

owing through the gravel of redds may, at times, be insufficient to llow development of the eggs. There is, however, no reason to suspect xygen deficiency for this particular redd.

In summary there was no demonstrable effect of fine material pon pre-eyed losses found in the streams studied.

Superimposition of redds is considered a factor in the natural gulation of population size (Hobbs, 1940). Superimposition was oted in a few cases in each of the streams in the present study. No ttempt was made, however, to evaluate superimposition as a factor in

egg mortality. In some of the obviously disturbed redds, extensive mortality in the eggs of the first spawning was not noted. Superimposition was most extensive in the upper section of Keuka Inlet where the late run concentrated. As most of the eggs from the initial run had been in the gravel for about 2 months, the majority of redds had reached the eyed stage or were hatching during the second spawning. Thus they were past the stage in which the ova are susceptible to injury by shock, and the only probable loss would have been by actual dislodgement from the gravel.

Both Briggs (1953) and Hobbs (1948) attempted to compare natural reproduction with the results obtained by artificial propagation. Both authors concluded that, up to the time of emergence from the gravel, natural reproduction is somewhat more efficient. The data presented here are also in accordance with this conclusion.

CONCLUSIONS

This study was designed to furnish data indicative of the success of natural spawning of rainbow trout in certain Finger Lakes tributaries. The values obtained are not necessarily estimates of population values. The distribution of spawning activity in the streams varies from year to year; consequently, a value obtained for a given section in a given year may apply to a very different proportion of the eggs spawned the next year. Indications are: (1) Finger Lakes tributaries provide a spawning environment of good quality free from the danger of excessive losses due to the deposition of fine material in the redds and (2) approximations of egg mortality values found by Hobbs (1948) may be applied to other salmonid populations maintained by natural reproduction.

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DIFFERENTIAL AGE AND SEX VULNERABILITY OF THE BLACK DUCK TO GUNNING[1]

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ABSTRACT

Data are given for the sex and age of 454 black ducks taken by gunning from a total of 6,641 banded during late summer and early fall from 1952 to 1954, and for 1,286 black ducks examined during hunter bag checks in the same years. Analysis indicates that males may be somewhat more vulnerable than females to gunning before they have been subjected to appreciable hunting pressure; also, that juveniles generally are more vulnerable than adults.

The black duck is the most important duck to the waterfowl hunters of New York State. Individual preference may differ and at certain times and places other waterfowl may predominate, but the total number of black ducks taken exceeds that of any other species. The black duck made up about 31 per cent of the hunter bag from 1952 through 1954.

Species such as the mallard and wood duck, in which sex is easily distinguished, may be subjected to preferential shooting of the male, particularly in the latter species where feathers from the drake are much in demand for fly-tying. On the other hand, it is rarely possible to distinguish the sex of a black duck on the wing, and most hunters cannot separate the sexes or ages in the bag. This species, therefore, is ideally suited to a study of differences in vulnerability to gunning because of sex or age. Data from banding operations in New York afford some information on this subject.

Banding stations were operated on refuge areas at Lake Alice, Perch Lake, Oneida Lake, Tomhannock Reservoir, the Oak Orchard Game Management Area, the Montezuma Marshes, and Quogue Sanctuary during August and September in an effort to band resident birds prior to the hunting season. From 1952 to 1954, a total of 6,641 black ducks was banded. The species, age, and sex were recorded for each. This allowed computation of any differential vulnerability among those reported taken later by hunters. Recoveries from the first hunting

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season following banding were received on 454 birds or 6.8 per cent of those banded. All returns other than by shooting were disregarded in this study.

The hunter bag-check data used comprise the records obtained during the same years that the banding was done. They were collected primarily from the larger marsh areas scattered throughout the State. In order to check a substantial number of hunters much of this work was confined to weekends throughout the season. It was conducted by many of the same personnel who operated the banding stations and was often done in the vicinity of the banding stations. These bag checks gave sex and age information on 1,286 black ducks. However, only 3 per cent were banded birds.

The data have been analysed with respect to vulnerability by comparing, for the two sexes and for the adult and juvenile age groups, the percentages that were recovered by gunning from the total number banded in each case. It is felt that adequate numbers were banded for such an analysis. It is recognized that there may be other influences that affect the rates of recovery differently, but in the absence of definite evidence they have been disregarded. The hunter bag-check data have been compared only in a rough way to the banding information since they derived, primarily, from an entirely different group of birds for which the prehunting-season composition was not known.

The records pertaining to sex vulnerability are summarized in Table 1. Based on the total first-year returns, drakes were 1.3 times as vulnerable to gunning as hens. This relationship is similar to that found by Bellrose and Chase (1950) among Illinois birds for which

Table 1. Comparative Sex Vulnerability Among Black Ducks Banded in New York and Taken by Gunning (1952-54)

Item	Male		Female		Males per female*
	Number	Per cent	Number	Per cent	
Ducks banded	3,579	xxx	3,062	xxx	xxx
First-year returns					
Total	270	7.5	184	6.0	1.3
In New York	84	2.3	38	1.2	1.9
Outside New York	186	5.2	146	4.8	1.1
Hunter bag check	667	xxx	619	xxx	1.1

* Ratio of the percentages for the two sexes in each case for the banded ducks, but of the number taken for the bag-check data.

the returns amounted to 6.3 per cent for males and 5.0 per cent for females.

The possibility of greater vulnerability among males was further strengthened when only the recoveries within New York State were examined. For this group males were 1.9 times as vulnerable as females. On the other hand, the corresponding value for returns from outside the State was only 1.1. Apparently the differential was lost soon after the birds joined migrating flocks and were subjected to gunning. Since the great majority of the birds banded were young of the year, it may apply primarily to juveniles before they have experienced appreciable hunting pressure.

For the hunter bag-check data, the ratio was 1.1, indicating little difference between the sexes among the general population of black ducks in New York during the hunting season.

The records pertaining to age vulnerability are summarized in Table 2. Based on the total first-year returns, juveniles were 1.4 times

Table 2. Comparative Age Vulnerability Among Black Ducks Banded in New York and Taken by Gunning (1952-54)

Item	Adult		Juvenile		Juveniles per adult*
	Number	Per cent	Number	Per cent	
Ducks banded	1,747	xxx	4,894	xxx	xxx
First-year returns					
Total	94	5.4	360	7.4	1.4
In New York	21	1.2	101	2.1	1.8
Outside New York	73	4.2	259	5.3	1.3
Hunter bag check	539	xxx	747	xxx	1.4

* Ratio of the percentages for the two ages in each case for the banded ducks, but of the numbers taken for the bag-check data.

as vulnerable to gunning as adults. When only the recoveries within New York State were considered the factor was 1.8. These findings are similar to those of other workers, notably Hanson and Smith (1950) for Canada geese in the Mississippi flyway. The corresponding value for returns from outside the State was 1.3.

For the hunter bag-check data, the ratio was 1.4.

These data indicate that, throughout the hunting season, juveniles are somewhat more vulnerable to gunning than are adults. They suggest that the differential may diminish as the season progresses.

In the foregoing tables, the records for all three years have been

TABLE 3. YEARLY DIFFERENCES IN AGE VULNERABILITY RATIOS AMONG BLACK DUCKS BANDED IN NEW YORK AND TAKEN BY GUNNING (1952-54)

Year	Adult		Juvenile		Juveniles per adult*
	Number banded	Per cent return	Number banded	Per cent return	
1952	725	4.6	1,626	7.4	1.6
1953	444	5.6	1,665	5.2	0.9
1954	578	6.2	1,603	9.5	1.5
Total	1,747	5.4	4,894	7.4	1.4

* Ratio of the percentages for the two ages in each case.

combined. Examination of the data for the individual years showed little variation in the ratios for sex vulnerability. With respect to age, however, that for 1953 differed appreciably from those for the other two years (Table 3). No explanation is offered for this, although the difference seems to have involved the juvenile birds primarily.

This problem is very complex and needs further study. Little is known regarding how sex and age vulnerability are affected if the hunting season is split, shortened or lengthened, or by changes in the bag limit.

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LETHAL OXYGEN CONCENTRATIONS FOR YELLOW PERCH

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ABSTRACT

The curve for the mean oxygen concentrations lethal to yellow perch over short exposure periods has been constructed for a temperature range from 53.3° to 70.0° F. An equation has been formulated to fit the data as plotted on semi-logarithmic paper. The procedure involves the gradual reduction of the oxygen content of water in a sealed container through respiration of the enclosed fish. Complete loss of equilibrium is used as the endpoint. The oxygen concentration at the endpoint corresponds closely to the lethal concentration for short exposures. Conditions to which the fish are exposed under this method approximate those resulting from intermittent discharges of organic, oxygen-demanding wastes into polluted streams more closely than do conditions produced by other methods which have been used to evaluate the tolerance of fishes to low oxygen concentrations. It is believed these data may be directly applied to such situations.

The tolerance of yellow perch (*Perca flavescens*) to low oxygen concentrations, as reported in the literature, appears to be subject to wide variation.

Wiebe, McGavock, Fuller and Markus (1934) determined the lethal oxygen concentration at 13.5° C. to be 0.35 p.p.m. Closed containers were used and the fish ranged in weight from 37 to 64 grams.

Powers (1938) quoted Powers, Rostorfer, Shipe and Rostorfer to the effect that yellow perch can absorb oxygen down to a level represented by 0.35 millimeters of mercury per liter at a pH from 8.6 to 6.3± with carbon dioxide from 0.15 to 14.0 millimeters.

Smith (1926) suspended caged fish at various depths in natural waters in order to obtain exposure to different oxygen concentrations. He reported that, at depths from 45 to 62 feet and at temperatures from 50° to 60° F., perch succumbed at oxygen concentrations up to 3.0 p.p.m. Mortality was reported at 61° F. in as short a time as 130 minutes at 2.35 p.p.m. of dissolved oxygen.

Moore (1942) used a method similar to that of Smith, although at both summer and winter temperatures. At summer temperatures he reported the lowest concentration at which perch were observed to live 24 hours to be 4.3 p.p.m., while the highest concentration which was observed to kill in 24 hours was 3.1 p.p.m. For winter temperatures, the

similarly observed concentrations were reported to be 1.8 and 1.5 p.p.m., respectively.

Cooper and Washburn (1949), in a study of the relation of dissolved oxygen to winter mortality of fish in Michigan, obtained much lower results than those reported by Moore. They listed a low oxygen-toleration level for perch at 0.4 to 0.3 p.p.m. Specifically, the oxygen values were determined in the upper 1 to 4 feet of water under the ice and those values were correlated with kill and survival data, from both observation and later collections of fish, in the lakes studied. A light kill was reported in two lakes, one of which had oxygen from 0.6 to 0.5 p.p.m. and the other from 0.5 to 0.05 p.p.m. In both, a good survival of perch was found. A very heavy kill of perch occurred in two others. The first had an inlet and fish were observed crowded into that region when the oxygen was from 0.3 to 0.1 p.p.m. There was a good survival of perch in this water, but the effect of the inlet could not be evaluated exactly. The other pond in which a heavy kill of perch occurred had oxygen ranging from 0.2 to 0.0 p.p.m. For this pond survival of perch was not mentioned.

Wilding (1939) used two methods. The first was a closed-flask procedure, in which water containing a small amount of oxygen was gradually admitted until one or more of the fish showed signs of asphyxia, at which time the analyses were made. By this method the asphyxial level for perch was reported to be as high as 2.76 to 3.00 p.p.m. of oxygen at temperatures from 20° to 27° C. As nearly as can be determined from his tables the mean or median asphyxial level for this species lies slightly above 0.76-1.00 p.p.m. interval.

In the second, a battery-jar procedure, fish were placed in a jar covered with a floating screen to prevent their access to the air. When one or more of the fish showed symptoms of asphyxiation, the water was analyzed. By this method, asphyxia in perch was shown to occur in the 1.51-1.75 p.p.m. oxygen interval at temperatures from 18° to 25° C. From these data it can be estimated that the median falls within the 0.76-1.00 interval.

Wilding recognized the possibility that injury from handling, or abnormal fish, might bias the estimation of the threshold. This appears to be one of the major difficulties to be surmounted in any determination based on the most susceptible of the fish, since it is difficult to estimate the degree to which the fish may be representative of the true population parameter.

He also reported that, within the temperatures involved in his

study, there was no effect from varying temperature. This probably confirms a high degree of variation in susceptibility of the fish, so that temperature effect could not be established. Such variation might be expected in threshold determination by this method.

Ellis (1937) reported that respiratory compensation may start at oxygen concentrations slightly below 5.0 p.p.m. He presented a graph showing such adjustments in a yellow perch subjected to three decreases and three increases of oxygen over a period of 130 minutes. Whether a continued low level of oxygen would have resulted in a maintained high respiratory rate, or whether, through acclimatization, the rate might have gradually decreased is not shown by the graph.

It has been reported that perch may live for extended periods of time in water containing little or no oxygen. Pearse and Achtenberg (1921) reported that some perch survived up to 2½ hours when lowered in a lake to a depth where the water contained 0.05 cc. per liter of oxygen (0.072 p.p.m.). They demonstrated that under these conditions part of the oxygen in the swimbladder was utilized. In another set of experiments water was pumped to an aquarium from a depth where it contained 0.06 cc. per liter (0.086 p.p.m.) and 5 cc. per liter of carbon dioxide (9.8 p.p.m.). Analysis showed the aquarium to contain 0.3 cc. per liter (0.429 p.p.m.). In the aquarium, one fish lost equilibrium in 4 minutes, several in 30 minutes, while one was still upright after 1 hour and 40 minutes. In a second run by the same method, the oxygen content of the aquarium not given, both fish used were belly-up in a few seconds. They righted themselves occasionally and were at the surface (where the oxygen could be expected to have been highest) periodically. After a 1-hour exposure, both fish recovered on removal to the surface water of the lake.

Moore (1942) indicated that at winter temperatures perch from 2 to 5 inches in length may survive 1.5 to 2.5 hours at an oxygen concentration of zero, while those 5 to 7 inches in length may survive 2.5 hours or longer.

This behavior of perch under low oxygen concentrations may introduce some doubt of the applicability of short-term lethal oxygen experiments beyond the time ranges covered by the data.

Shepard (1955) discussed variation in the criteria used to describe the ability of fish to "tolerate" hypoxia. He suggested that the oxygen pressure causing fish to exhibit respiratory distress (Wilding's experiments) is higher than the pressure causing fish to lose equilibrium (Townsend's experiments), which is higher than the level at which

short-term lethal effects are noted (Graham's experiments) and even higher than the pressure observed when fish die in closed containers (referring to Lozinov's studies). He suggested the adoption of a standard procedure to define tolerance. It should be pointed out in reference to these criticisms that, with the exception of Wilding's method which has been previously discussed, any oxygen content which will cause a fish to lose equilibrium will, if continued, result in death. Further, proper adjustment of volume in closed containers produces a sufficiently slow reduction in oxygen that the oxygen concentration at turn-over time closely approximates the concentration at death.

Shepard used the oxygen concentration that just failed to produce 50 per cent mortality and the experimental period was extended to 5,000 minutes. Fish were introduced directly into the concentration at which the studies were to be conducted. He noted that as such solutions approach the incipient lethal level a few deaths may occur in a relatively short time, apparently representing abnormal fish, or fish unable to make the physiological adjustment. He also reported that a burst of activity on introduction to water with a low oxygen content may result in an initial turn-over and a later recovery.

While it is standardized, the method recommended by Shepard is abnormal as far as representing any natural conditions, and it appears to measure not only tolerance to low oxygen under the specific conditions but also rate and ability to make physiological adaptation. Neither does the chemical analysis of a low-oxygen-content water, as prepared by the method used by Shepard, correspond with that of a water of similar content in a stream or pond.

In nature, lowered oxygen is usually due to a progressive reduction over a rather short period as a result of bacterial action on an organic waste, or reduction caused by the respiration or decomposition of plant or algal growth. Darkness, or low light intensity, may contribute to such conditions. Only in case of a direct chemical combination with oxygen, caused by certain chemical discharges, is the rate of reduction abrupt. Extremely long exposures to critically low oxygen generally occur only under ice cover, producing winterkill.

The usual short-period exposures may be duplicated most readily by a sealed-container procedure in which lowered oxygen caused by respiration of the fish substitutes for that caused in the stream by bacterial action or by respiration of chlorophyll-bearing plants. The high burst of activity noted by Shepard is not usual and the first turn-over is commonly final. The results can be applied directly to the

evaluation of conditions which result from stream pollution and which are commonly of short duration. The closed-container method was, therefore, used in this study.

EXPERIMENTAL PROCEDURE

The basic procedure as previously described (Burdick *et al.*, 1954) used as the endpoint the conditions present when the fish loses equilibrium and rests motionless except for respiratory movements. The close correlation of this point to the lethal point, as previously noted, has been confirmed for yellow perch, since many fish, especially at the higher temperatures, failed to recover on removal to water with a satisfactory oxygen content.

Rome Hatchery springwater was used as the experimental water. A complete analysis of this water has been given in the foregoing publication by the authors.

The fish used were originally from Delta Lake, an impoundment in the Mohawk River, though they entered the hatchery ponds through the supply line from the lake. After collection they were acclimatized to the springwater for several months and a period of more than 48 hours was given for each temperature acclimatization. These step-wise temperature increases were made at four levels from 53° to 70° F. in progression from the lowest to the highest.

Previous work had indicated that carbon dioxide, alkalinity, and pH did not vary sufficiently to produce a significant effect, so these determinations were not made on the test solutions during the course of this study.

The oxygen concentration in the test solution at the endpoint was determined by an iodized alkaline-iodide sample blank procedure similar to that described by Ellis, Westfall and Ellis (1946). Length was recorded to the nearest millimeter for all fish used in this study. The supply of fish held at an experimental temperature constituted controls for that temperature.

DISCUSSION

In April, May, and June, 1955, eighty yellow perch, ranging in length from 77 to 116 millimeters, were used to determine a short-term lethal oxygen concentration. Twenty fish were used at each of the four temperature levels from 53° to 70° F. In this part of the study the fish were all of Delta Lake stock.

It was later decided to try to extend the curve to higher temperatures, but Delta Lake fish were not available and a supply of perch was obtained from Oneida Lake in August 1955. After a short period of acclimatization to water and temperature these fish were used. The results failed to fit the previously formulated curve.

In the earlier part of the study, the Delta Lake perch were observed to be in spawning condition so it was impossible to determine whether the variation observed was due to a higher metabolic rate because of condition or to a difference between the two stocks, complicated by the larger size of the Oneida Lake fish. It was believed desirable to check the validity of the Delta Lake results in a different time period.

In the fall of 1955, an additional supply of Delta Lake fish was obtained from the hatchery ponds and transferred to hatchery springwater where they were held until and during experimentation which was started in December 1955 and concluded in January 1956. Ten fish were used in each of the concentrations from 54° to 70° F. Lengths ranged from 85 to 140 millimeters.

The median, arithmetic mean and logarithmic mean were computed for both sets of data. Since no significant differences were found between the means, the data were combined and used to compute the regression line and its equation.

The three sets of data are presented in Table 1. It can be observed that the logarithmic mean generally more closely approximates the median than does the arithmetic mean. Since this indicates a better fit for a logarithmic distribution, logarithms have been used to calculate the standard deviation and standard error. However, the use of an arithmetic progression probably would not have introduced an appreciable amount of error.

In order to combine the data at 53° and 54° F., a weighted average has been used which gives a figure of 53.3° F. for the average temperature.

The mean lengths of the fish, as well as the range of sizes at each temperature, are also given in Table 1.

The mean exposure time varied at the different temperatures, that in the original run ranging from 137 minutes at 70° F. to 316 minutes at 53° F. In the second run, the mean times ranged from 227 to 347 minutes, the lowest at 65° F. and the highest at 70° F. For the combined data, the mean times were 207 minutes at 70° F. and 320 minutes at 53.3° F.

Table 1. Summary of Data on Lethal Oxygen Concentrations for Yellow Perch

Number of fish	Temperature in degrees Fahrenheit	Mean length (millimeters)	Range of length (millimeters)	Oxygen concentrations found lethal (in p.p.m.)					Range of values for logarithmic mean	
				Minimum	Maximum	Median	Arithmetic mean	Logarithmic mean	Standard deviation	Standard error
April, May, and June, 1955										
20	$53 \pm \frac{1}{2}$	102.4	90–110	0.37	0.77	0.535	0.545	0.535	0.444–0.645	0.513–0.558
20	$60 \pm \frac{1}{2}$	96.8	79–116	0.48	0.88	0.595	0.626	0.616	0.513–0.738	0.591–0.641
20	$65 \pm \frac{1}{2}$	87.4	77– 97	0.51	1.10	0.725	0.715	0.702	0.583–0.848	0.673–0.733
20	$70 \pm \frac{1}{2}$	90.3	82–104	0.47	1.34	0.755	0.780	0.763	0.623–0.936	0.729–0.799
December and January 1955–56										
10	$54 \pm \frac{1}{2}$	93.3	85–105	0.33	0.75	0.560	0.528	0.517	0.404–0.663	0.478–0.572
10	$60 \pm \frac{1}{2}$	94.2	88–103	0.37	0.83	0.690	0.675	0.639	0.465–0.878	0.580–0.704
10	$65 \pm \frac{1}{2}$	94.8	89–105	0.56	0.88	0.685	0.705	0.698	0.600–0.830	0.666–0.732
10	$70 \pm \frac{1}{2}$	95.7	85–140	0.58	0.95	0.750	0.760	0.752	0.604–0.935	0.701–0.805
Combined data										
30	53.3	99.3	85–110	0.33	0.77	0.535	0.539	0.532	0.431–0.650	0.510–0.549
30	$60 \pm \frac{1}{2}$	95.9	79–116	0.37	0.88	0.620	0.642	0.623	0.495–0.785	0.597–0.650
30	$65 \pm \frac{1}{2}$	89.8	77–105	0.51	1.10	0.695	0.711	0.701	0.589–0.834	0.679–0.723
30	$70 \pm \frac{1}{2}$	92.1	82–140	0.47	1.34	0.750	0.773	0.759	0.630–0.916	0.734–0.786

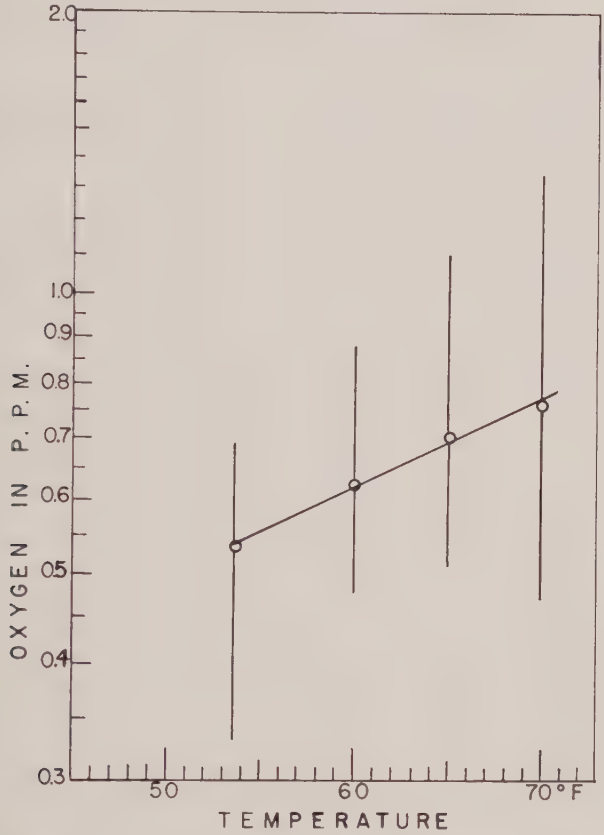

Figure 1. Mean lethal oxygen levels for yellow perch from Delta Lake; range of individual data shown by vertical lines.

The plot of the logarithmic means for the concentrations at each temperature and the line formed by the regression equation, calculated by the method of least squares according to Bliss (1952), appear in Figure 1.

The equation

$$\text{Log } Y = 0.00951X - 0.77926$$

represents the best fit for the data.

Pearse and Achtenberg (1921) showed perch may enter water containing insufficient oxygen to support life and remain there for some time through absorption of oxygen contained in the swimbladder.

With the presence of an extraneous source of oxygen available in

addition to that from the water, it seemed desirable to explore any effects from the fish drawing on this supply when the concentration dropped to a critical value. Should such supplementation have occurred, the oxygen in the water could have been still further reduced during the period involved. If such behavior introduced appreciable error, the oxygen concentrations at the endpoint would have been inversely correlated with the time of exposure. A time progression was prepared for each concentration, and the figures for the concentrations represented by the half with the smaller time periods and those for the half with the longer periods have been summed separately. Comparison showed no definite correlation in the data from the several temperatures. It is, therefore, assumed that this physiological adaptation did not account for a significant error in the results.

Another approach to the evaluation of possible error caused by the availability of small amounts of oxygen from the swimbladder would be to determine the time period during which this source would support the fish in a zero-oxygen water. Such a water was prepared by sweeping the oxygen from the experimental water by means of a stream of nitrogen gas. While this procedure will also remove any carbon dioxide and slightly alter the pH, it was believed such a water might be used for comparison without introducing serious error. It does not, however, represent the chemical constituency of a water in which natural processes have removed the oxygen. Under these conditions, and at a temperature of 70° F., the average perch reached the endpoint in approximately 4 minutes. The most resistant required almost 7 minutes.

Shepard (1955) demonstrated that a minimum period is required for the oxygen deficiency within the fish to develop and result in turn over. Even if all the delay in turn-over were to be ascribed to the use of swimbladder oxygen, with none allotted for the reduction of the oxygen in the blood and tissue at the time of introduction, the small lag period could not result in significant error in comparison to the total time for each experiment. Assuming a uniform rate of oxygen removal, the possible error may be computed, although, since oxygen utilization may be assumed to be less with the lack of activity found when the endpoint is neared, the figure would probably be too high. The lowered metabolic rates at lower temperatures might increase the time of turn-over at zero oxygen, but the increased experimental time under these conditions would tend to compensate for this, so it was not considered necessary to carry this check further.

SUMMARY AND CONCLUSIONS

It was found that no statistically significant differences existed between the data collected from April through June 1955 and similar data taken in December 1955 and January 1956. It has been concluded that these data are representative of this particular stock of perch and they have been combined for this presentation. The variation evident in the Oneida Lake stock should be studied further in order to evaluate the cause and significance of the differences found and to determine the effect of size and method of handling. In this respect what was considered as minimum acclimatization had been given since it was desired to use these fish as soon as possible.

It can be noted on the graph that for a temperature of 56+° F., the concentration given by Weibe *et al.* (1934) has been confirmed. The graph and equation permit the estimation of the short-term lethal oxygen concentrations at other temperatures.

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A GRAPHICAL METHOD FOR DERIVING THRESHOLD VALUES O TOXICITY AND THE EQUATION OF THE TOXICITY CURVE

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ABSTRACT

A hypothesis is set up that the curvature found in logarithmic plots c concentration against time for death in toxicity studies is induced by failure c the effective range to conform to the axes of the paper. Translation may b effected by subtracting the threshold value from concentration and a minimur time for death from time. When this is done the curve becomes a straight lin and represents a simple inverse proportion.

A graphical method is presented by which these correctives may be ap proximated and an equation for the original curve derived.

The major usefulness, other than providing a simple method of obtainin the equation of the curve, lies in the evaluation of the threshold concentratio which can be used to establish safe disposal rates for toxic wastes.

A toxicity curve may extend from a minimum time at high con centration (the period required at maximum effective concentratio for the specific physiological reaction to produce death) to an infinit time at extremely low concentration. At these extremes, one end be comes asymptotic to a perpendicular to the time axis; the other, to perpendicular to the concentration axis.

On arithmetic paper, the curves resemble equilateral hyperbola which have been rotated 45 degrees. The extremes approximat straight lines and frequently have been plotted as such. Powers (1917) recognized this resemblance and plotted the reciprocal of time agains concentration, producing a sigmoid curve the central portion of whic approximated a straight line. He called this the "theoretical velocit of fatality curve", and the point at which the extended straight portio cut the concentration axis he designated as the "theoretical threshol of toxicity concentration". He noted that some substances did no appear to be susceptible to this type of treatment. Consideration of th form of Powers' curves seems to indicate the true threshold value t be somewhat lower and, to the extent that sigmoid curvature devel oped, the failure of the data to conform to his hypothesis.

A true equilateral hyperbola should plot as a straight line on loga rithmic paper. However, although straightened to a certain extent toxicity curves are found to retain a definite curvature.

Herbert and Merkens (1952) in a study of the toxicity of cyanid to rainbow trout treated the logarithmic plot of their data above th

point of maximum inflection as a straight line. This ignores the generally curvilinear character of their data and an abrupt break occurs in the slope near the inflection.

Many authors have fitted similar curves by means of multiple-degree equations. This does not appear to be wholly satisfactory, since the process is laborious and often the result is not in close agreement with the actual data points. The variability is generally believed to be due to experimental error in the data.

The original curves appear related to a simple inverse proportion where xy equals a constant. This is also the equation for an equilateral hyperbola which has been rotated 45 degrees. Opposed to this concept is the fact that the data cannot be solved for the constant and the logarithmic graph is not a straight line.

Shepard (1955), in studies of the tolerance of speckled trout to low oxygen concentration, recognized that at zero oxygen a certain minimum time is required for death to occur. By subtracting this experimentally determined value from the time for death at various oxygen levels he successfully straightened the plot of his data.

Since, at high concentration, there would also be a range at which the elapsed time for death would tend to become constant, a similar time corrective might well be applied to a toxicity curve. The experimental determination of this value is theoretically possible, although error in the estimation of the exact time of death increases as the time decreases. There is also danger of a change in physiological reaction or an effect from increasing osmotic tension as the concentration is increased. Subtraction of this time corrective will straighten the curve for higher concentration, but curvature will still be present since the points for low concentration will not be significantly affected.

Concentration can affect time only in that range lying between the concentration producing a minimum time for death and the threshold value for concentration where exposure time becomes infinitely large. This would suggest that a similar corrective should be applied to concentration if it could be determined. Subtraction of these two correctives before plotting would be equivalent to translating the curve so that the effective range would correspond to the axes of the graph paper. If a simple relationship exists, the curve would then become a straight line on logarithmic paper.

This theory was checked by subtracting the experimentally determined time for death in cyanide at high concentration from time values taken from a curve in which the lowest concentration failed to

produce more than 40 per cent mortality in 10 days exposure time The latter concentration was considered as the threshold value of 5 per cent mortality and was similarly subtracted from the concentratio values for the same points. The resulting data, plotted on logarithmi paper, approximated a straight line.

It was then predicated that it should be mathematically possibl to compute the two constants used as correctives from the equation

$$(x-a)\ (y-b) = k$$

where a corresponds to the threshold concentration and b represent the minimum time for death at high concentration.

The data were plotted and fitted with a smooth curve, after it wa found that use of the actual data points introduced too much mathe matical variability. The coordinates of selected points on the curv were used to form the equations which were then solved simultaneousl for values of a and b. The value of the constant k could then be deter mined (Figure 1).

Difficulty was found in reading the curve with sufficient exactnes as the mathematical treatment tends to increase any error involve This equation also results in the rotation of data, since a slope of 1 : implied. This became evident when the constant b was found to b negative, indicating that time should be added, rather than subtracte in shifting the axes of the data. Such a hypothesis is untenable and th use of this equation for the determination of the constants is invalid Since the equation assumes a slope of unity it could be applied onl where the data represent a true equilateral hyperbola.

Due to the characteristics of logarithmic paper, a small tim correction becomes insignificant at low concentration. This part of th curve can be considered reasonably accurate when corrected by sub traction of the threshold value only. Only one set of points produce by subtraction of arbitrarily chosen values will result in a straight lin Undercorrection produces curvature in the same direction as th original plot, while overcorrection will produce curvature reverse from the original. It is thus relatively easy to approximate this lin rather closely. The value subtracted when this line becomes straigh represents an approximation of the threshold value. The line is the extended to parallel the original curve. The subtraction of the thre hold value is continued over the entire length of the original curv The points will be observed to deviate gradually from the extende straight line, approaching the original curve most closely at the poi

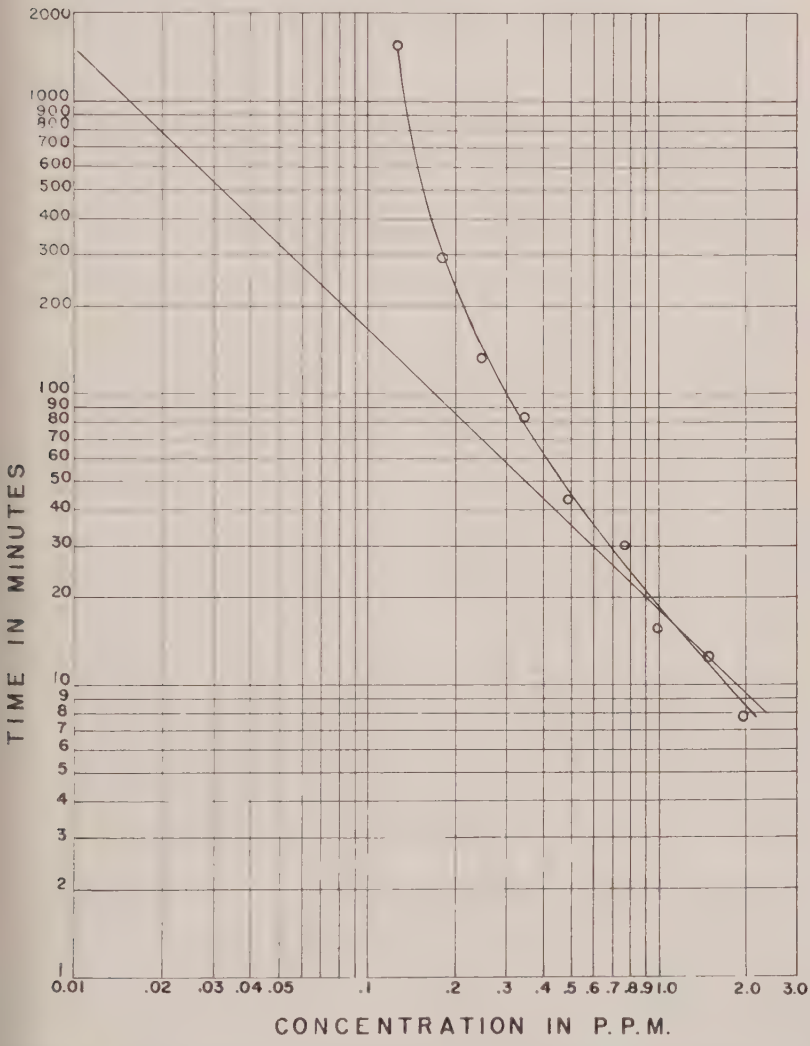

Figure 1. Toxicity curve and translation to a straight line according to the mathematical solution of the equation $(x-a)\ (y-b)=k$. In this case $a=0.118$; $b=-1.52$; $k=17.002$.

of highest concentration. These points, representing the correction of the original curve by the threshold concentration are connected by a curved line.

The distance between this curved line and the straight line represents the correction constant for time. This is illustrated in Figure 2

in which it is indicated to be 2.2. Variation in value at points along th line may represent cumulative error, in major part due to error in th plotted curve, or, if the time correction is not insignificant in the rang at which the straight line is constructed, failure to consider the tim corrective. In the latter case, correction may be made by successive ap proximations, using each time the latest estimated time correction i formation of the straight line. Generally a slight error in the minimun time for death is not significant, as this figure has little use. If under estimated, as it may be when construction of the straight line is base on ignoring a correction which would result in shifting the position o the line, the threshold value will be slightly overestimated.

The equation for the straight line on logarithmic paper may b calculated by any of the usual methods and an equation of the follow ing form results:

$$\log Y = a^1 - b \log X$$

where a^1 = mean logs $y + b$ (mean logs x).

The equation for the original curve may then be obtained by sub stituting log (y − the time constant) for log Y, and log (x − th threshold value) for log X in the above equation. The closeness of f of the equation may be shown by solving for y, using selected valu of x. These have been plotted on Figure 2.

If only minor deviations are found between coordinates derive from this equation and the plotted curve, it may be assumed that clos approximations of the threshold value and the minimum time for deat have been obtained. Unless successive approximations are used, or th straight line is formed where time correction is not significant, th threshold value must be considered a more accurate determination tha the minimum time for death.

Both corrections are determined as characteristics of the curve an thus have higher accuracy than any method which involves extrapola tion of the data.

The threshold value may be used in establishing safe disposal co centrations for toxic wastes. These have previously been based o extrapolations from long-term experimental exposure with the usu difficulty of maintaining exact concentrations for such long exposure or on ratios between specific exposure periods which are intended t correct for any differences in slopes.

This treatment results in the translation of the data to the axes o the graph paper and confirms the assumption that the curve forme

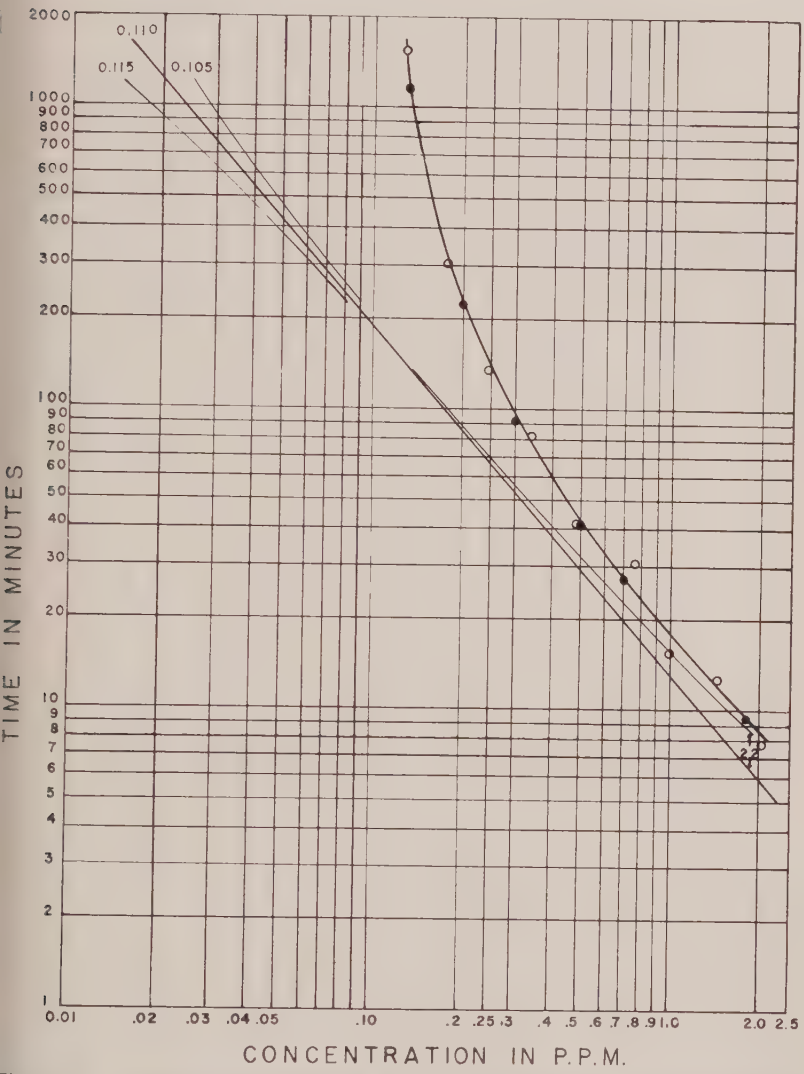

Figure 2. Graphical determination of the correctives for the toxicity curve and solution of the derived equation for agreement. Open circles represent determined values; solid circles, solution of selected points from equation.

When time is plotted against concentration on logarithmic paper is produced by the failure of the data to conform to the axes of the paper. If only the effective range is considered, the data appear to represent a simple inverse proportion.

Several toxicity curves have been treated by the preceding metho and have appeared to confirm this hypothesis. Final confirmation wi however, have to await testing by application to many more sets experimental data.

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NIGHT COLLECTION OF FISH WITH ELECTRICITY[1]

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ABSTRACT

The populations of carp, yellow perch, and smallmouth bass in East Masonville Lake (30 acres) were estimated with the aid of an electric surface device which has been described in detail (Loeb, 1955). Briefly, it consisted of four 7-foot electrodes suspended from a wooden scow and powered by a 230-volt alternating-current generator.

Daylight operations were found to be effective only under special circumstances. However, the number of fish collected at night with the aid of spotlights was greater than expected. Accordingly, electrical techniques for night operation were developed and then used successfully in Lamoka and Waneta Lakes. Fish were also successfully collected from Hyde Lake. The device failed in Onondaga Lake because of the low water resistivity.

During the summer of 1954, daylight experiments were carried out with a new-type electrical surface device. The tests clarified, to some extent, the relationships among electrodes, their effective electric fields, and the fish involved (Loeb, 1955). The original device consisted of four 7-foot rod electrodes which were hung from booms extending from the corners of a 1,000-pound wooden scow. The electrodes were powered by a 230-volt alternating-current generator with a capacity of 6.7 amperes. A considerable amount of shocking was carried out in Lake Lamoka for the express purpose of developing a method of carp control and, although the device proved to be impractical from this standpoint, it did provide a good method for collecting several species of shallow-water fish, especially in stumpy and weedy areas.

The limitations of this device (and all alternating-current techniques) were revealed by defining the extent of the effective electrical field around each electrode. The effective radius proved to be quite small (radius varies in water of different resistivities) in the water tested. A larger electric field could be obtained by adding electrodes at stratagic points or increasing generator voltage, but electrode increase would be limited by generator capacity. Furthermore, doubling of generator voltage would not increase the effective radius proportionately, although danger to the operator would more than double.

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[1] A contribution of Federal Aid in Fish and Wildlife Restoration Project F-9-R. The writer is indebted to Messrs. David C. Haskell and A. C. Petty, New York State Conservation Department, who reviewed this paper, and especially to Mr. Kenneth Stafford who originally suggested the use of the present technique.

In summation it may be concluded that alternating-current de vices are most effective where fish can be cornered in their rathe limited fields.

During the summer of 1955, the device was used again to estimat the populations of carp, perch, and bass in East Masonville Lake. Mos of the fish were captured during daylight hours and catches wer small, but one night operation was attempted during which a large number of fish were successfully shocked. Another carp populatio study was carried out in Waneta Lake where all operations were con ducted at night and again fish were collected in far greater numbe than would have been possible during the day.

Safety and operating features of the 1954 device were poor, bu improvements were made during the night fishing operations.

FEATURES OF THE IMPROVED DEVICE

High standards must be maintained for safe, efficient operation o any electric device, especially when carried out at night. Such main tenance proved more difficult than was anticipated.

Efficient operation was assured (insofar as our knowledge per mitted) by a correct placing of equipment such as electrodes and lights Methods of insuring safety were applied as the need became apparent Safety and efficiency are, of course, closely related and good wor habits are essential to both. But the very nature of the techniqu created certain unique problems.

Night operations were carried out within the circle of light fro the boat which moved over the surface of the lake, and this restrictio of scope was coupled with constant noise from the generator an motor, as well as occasional discomfort due to cold and rain. As a re sult it was difficult to remain alert and drowsiness often ensued although occasional coffee breaks helped to dispell the aura of isola tion. This description is intended to emphasize the extreme danger inherent in the operation. A dreaming crew member can easily b thrown into the water if the moving rig hits a stump, dock or boat. A late swimmer might be electrocuted without anyone's knowledge.

The design which proved safest and most efficient is illustrated i Figure 1. Most fish were first shocked by the pair of forward electrode and were quickly reincapacitated by the rear set. The latter wer placed forward of the middle of the boat to eliminate the danger t a man who might fall into the water. All electrodes were made o flexible cable and were simultaneously controlled by a pair of long

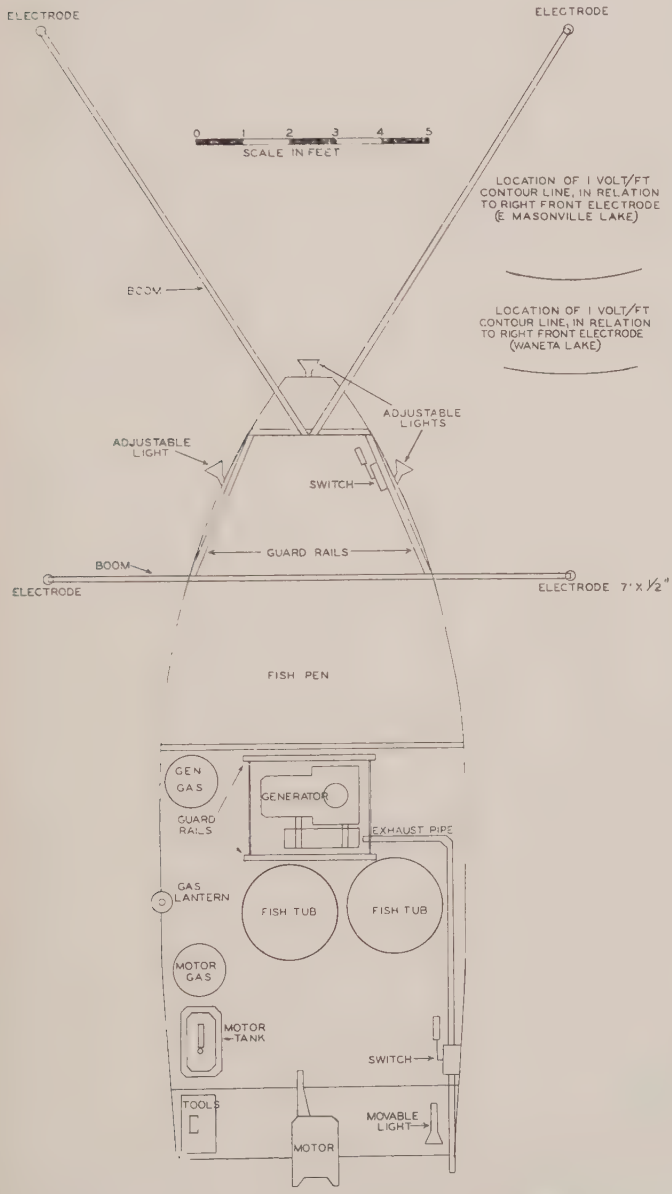

Figure 1. Diagram of equipment for night shocking as used in Waneta Lake. For efficient operation in other waters, position and number of electrodes might be modified. Advantage is sometimes gained by enlarging the effective field around one electrode by disconnecting the other electrode of similar polarity.

handled switches one of which could be operated by the motorman and one by the dipnetter in the bow.

Light was supplied by 115-volt mounted spotlights, an emergency gas lantern also mounted on the boat, and flashlights. All circuits were laid out in series to prevent shorting and were securely fastened to the boat. Lighting was not controlled by the electrode switches. Terminal receptacles were not housed since soaking did not cause shorts.

Operation of the rig demanded constant movement about the boat and safety features had to be adapted to this requirement. Accordingly, guard rails were raised on the bow and placed around the generator. Dangerous footing was eliminated by general neatness which included penning the fish taken, and personal danger was minimized by wearing boots and life jackets.

The electrode arrangement presented in Figure 1 does not necessarily apply to all waters, but should be varied in accordance with water resistivities. More are needed in soft waters where effective fields are smaller. Relationships between resistivities and electrode numbers are presented in Table 1 for seven different types of water. Two hypothetical lakes and sea water are included to indicate expected results over a complete range of water resistivities.

COMPARISON OF DAY AND NIGHT SHOCKING IN EAST MASONVILLE LAKE

This small lake (in Delaware County) contained a fish population composed largely of carp, smallmouth bass, and yellow perch. Gill and trap netting were ineffective in taking fish for population estimates and seining was impossible due to snags. Therefore, sampling was finally carried out with the shocker and the results clearly illustrate the relative efficiency of night fishing with a device of this type.

Most of the collecting was done during the day by running the shocker along the shoreline, and all captured carp, bass, and perch were fin clipped and released. Catches (one fish per dip) were generally small except for instances in which schools of small carp were shocked in a small bay. The size of these schools could not be determined because of high turbidity, but on three successive days 50, 250, and 600 carp were captured—each group in a matter of minutes. Succeeding daylight operations produced as few as seven carp per day. Then, in one night, a total of 175 carp and 50 each of perch and bass were captured at a rate of one fish per dip. The relative

Relationships between Electrical Equipment and Water Resistivities

Lake	Turbidity	Resistivity (ohms per centimeter cube at 70°F.)	Effect on speed of generator*	Approximate radius of field about any electrode (in feet) for three degrees of voltage per foot§			Possible number of electrodes†	Remarks
				3 0	1 5	1 0		
Hypothetical *A*	—	over 25,000	None	Very small			Over 10	Low conductivity and small effective fields; compensate by adding electrodes
East Masonville	High	22,500	None	3	4	5 1/2	8	Same as above
Hyde	None	10,000	Very slight noticable drag	Intermediate between East Masonville and Waneta Lakes			6	
Waneta	Medium	5,000	Distinct drag	4	6½	7½	4	
Hypothetical *B*	—	‡	Heavy drag	—		7 1/2–10 (est.)	2 4	Greatest possible radius of field of effective voltage; generator not overloaded
Onondaga	Very high	500	Reduction to less than half top speed resulting in less voltage output	Probably as small as for hypothetical Lake A			None—unless pulsator is used	High conductivity; amperage drawn approximately 45 times that in East Masonville Lake and 11 times that in Waneta Lake
Sea water	Clear to very high	Very small		—	—	—	None—unless pulsator is used	Large generator necessary

* Generator was Homelite, 180-cycle, 230-volt, A.C., with a rated capacity of 6.7 amperes; electrical equipment operated comprised four electrodes (7 feet by ½ inch) and four spotlights.

§ In all cases, areas of electrodes of opposite polarity were equal.

† Plus four spotlights; electrodes should be 6 to 7 feet long for greatest efficiency.

‡ May be calculated from: $\frac{\text{resistivity of Lake } X}{\text{resistivity of Lake } B} = \frac{6.7}{\text{current drawn in Lake } X}$, when both resistivity and current drawn are known for Lake *X*.

Table 2. Comparison of Diurnal and Nocturnal Shocking in East Masonville Lake

Period and time of shocking	Number of fish shocked	Remarks
Three weeks of daylight shocking around shoreline; approximately fifteen 6-hour days	200 carp 25 bass 25 perch	Catch per hour less tha three
Three 5-minute periods of daylight shocking in small bay	900 carp	Situation profitable, but rar and unpredictable
One night (2 hours) of shocking around shoreline	175 carp 50 bass 50 perch	Catch per hour over 135 would probably vary fro night to night, but woul average high

efficiency of night fishing was first illustrated by this experience and i pointed out in Table 2.

Conditions for shocking in East Masonville Lake were poor i contrast to those in some other waters. Resistivity of the water wa approximately 22,500 ohms per centimeter cube at 70° F. and, con versely, conductivity was relatively low and the effective fields wer small. In addition, high turbidity reduced visibility and most of th vague fish shapes which could be seen at night darting from shor across the path of the boat were missed by the dipnet.

Nevertheless, it is estimated that twice as many carp and severa times as many bass and perch could have been taken in the same tota time if all collections had been made at night. The fish were close t shore during the night and were more easily seen.

During the period of shocking a representative size group of eac species was collected, as was later proved when the lake was treate with rotenone.

CARP SHOCKING IN LAMOKA AND WANETA LAKES

During the spring of 1955 approximately 1,000 carp were shocked fin clipped, and released in Lamoka and Waneta Lakes in Schuyle County (600 and 800 acres, respectively). All fish were captured a night over a period of 3 weeks and at a far greater rate than was ex perienced during extensive daylight shocking. Captures and release were made throughout the shallower areas of both lakes, and the dis tribution of fish and effort was much more random than would hav been possible by netting. In Waneta Lake carp were captured at th rate of about 100 per night, and in Lamoka Lake at half that rate

The Lamoka Lake population study was finally abandoned because heavy weed growths interfered with the motor; an air driven boat might have overcome this difficulty.

The Waneta Lake population was sampled again during midsummer. Over 1,100 carp (including recaptures) were taken at night with the electric device over a period of 3 weeks, and again the rate of catch far surpassed those of previous trap netting, seining, and daylight shocking efforts.

Lamoka and Waneta Lake water, with a resistance of 5,500 ohms per centimeter cube at 70° F., was a good conductor of electricity, and the effective field surrounding each electrode was relatively large.

NIGHT SHOCKING FOR OTHER SPECIES

The device was tested briefly at Hyde Lake (Jefferson County) which is deep and clear, with a resistivity of approximately 10,000 ohms per centimeter cube at 70° F. It is estimated (on the basis of an accurate count over a 2-hour period) that fish could have been captured in the following numbers during 8 hours of night shocking: 25 large walleyed pike, 25 large northern pike, 50 bass (8 inches or more) and 250 assorted sunfishes. A collection of this size would be sufficient for limited studies.

A night test on Onondaga Lake (near Syracuse) failed almost completely due to the low water resistivity of about 500 ohms per centimeter cube at 70° F. the result of industrial pollution. The smallest (2 x ⅛ inches) of electrodes were water shorted, generator speed was reduced to less than half of normal, and the effective fields were probably very small. The required amperage was actually 11 times that for Waneta Lake. Electric shocking is impossible in rare lakes of this type without addition of an amperage-reducing pulsator. Despite these difficulties and extreme turbidity, a dozen carp, one sheepshead, and several each of walleyed pike, shiners, perch, and suckers were collected in 3 hours.

Night shocking in Waneta and Lamoka Lakes was phenomenal at times. On an average night (two men fishing for 6 hours) from May to September, fish other than carp were shocked in substantial numbers (Table 3).

On some nights during the spawning season as many as 1,000 legal-sized bass and concentrations of many thousands of alewives (often over deep water) and bluntnosed minnows were shocked. Suckers were most often shocked around stream mouths during the

Table 3. Number of Fish Other Than Carp Shocked on an Averag Night* in Waneta and Lamoka Lakes

Species	Number shocked†	Frequency in lake‡
Brown bullhead	75	Abundant
Smallmouth bass	10	Rare
Largemouth bass	250	Abundant
Pickerel	50	Abundant
Chub and common sucker	200	Common
Pumpkinseed and bluegill sunfish	2,000	Abundant
Alewife	5,000+	Abundant
Black crappie	None	Abundant in deep wate
Yellow perch	Very few	Abundant in deep wate
Rock bass	Very few	Rare

* Two men fishing for 6 hours.
† Estimated visually since time did not permit accurate counts.
‡ Based on results of electric shocking and previous trap-net studies whic resulted in the capture of some 36,000 fish.

spring, but were found in all shallow waters during the summe Bullheads were most common in swampy areas, especially in the spring Pickerel, which were never seen during the day, actually jumped int the boat several times each night.

The rate of capture of several of these species far surpassed mos netting efforts. Pickerel, bass, bluegills, sunfishes, and alewives certainl fell in this category. Possibilities for collection, population studies, o even control are great. In addition, information can be acquired con cerning fish movements and locations since individual fish are shocke and recorded in an instant, but in netting the data apply to a perio of time.

SPECIAL TECHNIQUES DEVELOPED FOR CAPTURING CARP

Because East Masonville Lake was extremely turbid and the effec tive electric fields relatively small, shocking in water over 3 feet i depth was unproductive. Carp were captured at an average distance o 5 feet from shore, at depths of 1 to 2 feet. The boat was run at abou twice walking speed, and the small carp (average size, 8 inches) wer picked up without reducing speed.

In Waneta Lake, carp averaging between 6 and 7 pounds i weight were occasionally found close to shore, but most were capture over depths of 2 to 15 feet at distances of 50 to 200 feet from shor Sharp dropoffs produced little, but broad, fairly level areas were quit productive when traversed again and again at a boat speed of 8 t 10 miles per hour.

Carp were often raised for the first time only after the third or fourth or even tenth pass over an area. It was not possible to determine whether they were repeatedly shocked or merely avoided the boat. Shocked fish often appeared at the side and well behind the boat, and were picked up in a return sweep at high speed. Two cooperating boats recovered more than twice as many fish as single boats working separate areas.

This method might not be efficient for any species but carp—and large ones at that, but it should be pointed out that these techniques were anything but obvious at the beginning of the night shocking experiments.

Theoretically, variations in techniques should be developed for each species in each water since success on a given night is related to physical conditions and unknown factors. For example, turbidity, rain and wind affect visibility. Species which are present in an area in great abundance on a given night may be almost absent on the following night. In fact, distribution often fluctuates noticeably in an hour's time.

EFFECT OF ELECTRIC FIELDS ON TURTLES AND SNAKES

Several water snakes (*Natrix sipedon*) were incapacitated by the device. As the fields overran them, they appeared to stiffen and in two cases the mouth opened wide. Two captured snakes recovered, but it is possible that a heavily shocked snake could drown.

Large snapping turtles remained incapacitated only while surrounded by the electric field. Thousands of painted terrapins were also shocked. The majority pulled in head and legs (perhaps involuntarily) but swam with greatly increased vigor after the field had passed over them. The terrapins could be touched repeatedly by the electrode itself without apparent ill effect. Although paralyzed while in contact with the electrode, they swam immediately when removed from the field.

CONCLUSIONS

Electric night fishing for certain species of fish in lakes is far more efficient than daylight shocking for several reasons. The water is usually calm, fish can be seen much more easily than during the day, and fish of several species often congregate in shallow areas at night. Tests to date indicate a usefulness where netting is impossible or inefficient.

The technique can shorten the time necessary for some population studies, and for routine collection of fish. Population estimates may be more reliable when based on random figures provided by shocking while errors resulting from poor sets, torn nets, poaching and funnel escapage are eliminated. The device may also be used to acquain sportsmen with numbers and sizes of fish in a given lake.

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GENERAL NOTES

AN EARLY ATTEMPT TO INTRODUCE PHEASANTS TO NORTH AMERICA[1]

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The currently accepted date for the first attempt to introduce the pheasant (*Phasianus colchicus*) in North America is 1790, when Richard Bache, son-in-law to Benjamin Franklin, imported and released "English" pheasants on his estate in New Jersey (Phillips, 1928). These birds, presumably black-necked pheasants (*Phasianus colchicus colchicus*), did not become established, nor were any attempts at stocking pheasants in North America successful until the Chinese ring-necked pheasant (*Phasianus colchicus torquatus*) was used nearly a hundred years later in Oregon.

An earlier attempt to establish black-necked pheasants in what is now New York State is recorded in Chapter 601 of the Colonial Laws of New York, passed November 1, 1733, entitled "An Act to Preserve the Breed of English Pheasants in this Colony" (New York State, 1894: 825-827). The law is quoted below in its entirety because of its incidental commentary on the privileges assumed by the eighteenth century aristocracy, and their control of the legal processes in their favor.

> "WHEREAS the Late Governour did place about half a Dozen couple of English Pheasants on Nutten Island, and first Pinnion'd them to the End they might Remain there to propagate their Species, With a view that their Encrease would Spread from thence & Stock the Country with their Kind.
>
> "AND whereas the Said Fowls have not only Encreased Vastly on the Said Island, but many of them already Spread over to Nassau Island, And in all Probability will Soon Stock the Country if people are Restrained from Destroying them for a few Years.
>
> "AND the present Governour being likewise Desirous that the whole Colony may Speedily be stockt with those Fine Fowls And to the End a Designe of Such publick Benefit may not be Frustrated, Be it Enacted by his Excellency the Governour, the Council & the Generall Assembly, And it is hereby Enacted by the Authority of the Same that whatever person or persons Freeman or Slave that Shall from & after the first day of December next Ensuing & During the Continuance of this Act wittingly & Knowingly Kill or Destroy any of the Said Breed of Pheasants their Young ones Chickens or Eggs Shall forfeit to his Majesty the Sum of ten Shillings Current Money of this Colony, one half whereof to him her or them who shall Prosecute & Sue for the Same before any one of his Majestys Justices of the Peace where Such offence Shall be Committed, Who is hereby Impowered & Required to hear & Determine the Same and the other half to & for the poor of the Respective Town, Mannor or Precinct, Where Such Offender Shall be so Convicted, And in Default of Payment thereof the Said Justice is further Impowered & Required by Warrant Under his hand and Seal to Commit Such Offender or Offenders to the Common Goal there to Remain for the Space of five dayes without Bail or Mainprise, Unless within that time the said Forfeiture is payd.
>
> "And for the Convicting of Such Offender or Offenders as Aforesaid, be it Enacted by the Same Authority, that Whatever Person or Persons with

[1] A contribution of Federal Aid in Fish and Wildlife Restoration Project W-23-R.

whom shall be found or by whom Shall be Exposed to Sale any of th Said Breed of Pheasants their Young ones, Chickens or Eggs, Shall h deem'd and adjudged guilty of the Said Offense & be thereof Convi unless he She or they Shall Prosecute and Convict some other Person have done the Same.

"And be it further Enacted by the Authority aforesaid, That if an Justice of the Peace Shall upon Complaint to him made or Informatio to him given, Neglect or Refuse to hear & Determine the same in purs ance of this Act, Every Such Justice so Refusing or Neglecting Shall Fo feit the Sum of three pounds in Like Money, as aforesaid, to be Recovere in any Court within the Same County, Where Such Justice doth Resid One half Whereof to the Person who shall Prosecute & Sue for the Sam and the other half to be paid to the Treasurer of the County where Suc Offence Shall be Committed, to & for the use of the Same County.

"Always Provided that it Shall be Lawful to & for the Governour Commander in Chief for the time being, to Kill Destroy or give away or Cause to be Killed Destroyed or given away from Nutten Island afor said any of the Said Breed of Pheasants, their young ones Chickens or Eg And so Likewise for any other Person or Persons Unto whome the San are or Shall be so given Not only to Keep or Kill them but also the Bre Reared therefrom in his her or their Farmes Plantations Seats or Yar Either in the Country or in any City, without incurring the Fine Penalty Imposed by this Act, anything therein Contained to the Contra thereof in any wise notwithstanding.

"And be it further Enacted by the Authority aforesaid, that this A Shall be and Remain of Force from & after the Before Mentioned fir day of December, Untill the first day of December which will be in th Year of our Lord one thousand Seven hundred & thirty Eight."

The "late Governour" of the first paragraph of the law, who brought th pheasants over from England, was Colonel John Montgomerie who, as Governo of the New York Colony, arrived in New York to take up his duties in Ap 1728 and served until his death in July 1731. The Nutten Island of 1731 now known as Governors Island, located in New York Bay about three-tent of a mile west of Long Island ("Nassau Island"). The "present Governour", whose request the law was passed, was Colonel William Cosby who was a pointed to succeed Montgomerie and served until his death in 1736.

Just when the pheasants were released is not known, except that the da was sometime between April 1728 and July 1731. In spite of their reported i crease and spread to Long Island, the pheasants apparently did not becom established, for there is no further record of them. The law protecting the expired in 1738 and was not reenacted.

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